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THE REVEGETATION OF VOLCANO ISLAND, LUZON, PHILIPPINE ISLANDS, SINCE THE ERUPTION OF TAAL VOLCANO IN 1911

By WILLIAM H. BROWN, ELMER D. MERRILL and HARRY S. YATES
(From the College of Liberal Arts, University of the Philippines, and from the Botanical Section of the Biological Laboratory, Bureau of Science, Manila, P. I.)

SIXTEEN PLATES AND TWO TEXT FIGURES

GENERAL DESCRIPTION OF VOLCANO ISLAND

Taal Volcano is a low cone with an oval crater which has an area of about 3 square kilometers. The highest part of the rim is on the southwestern side (border) and has an elevation of approximately 300 meters. Some parts are considerably lower, 130 to 150 meters. The crater is roughly in the center of Volcano Island, which is triangular and has an area of about 25 square kilometers (*Plate IV*). The island in turn is in the center of Lake Bombon, which has an area of approximately 320 square kilometers (*text fig. 1*). For a concise account of the geology of this region see Adams.[1]

On Volcano Island are a number of old craters and cones, the most prominent of which is Mount Binintiang Malaqui, situated at the northwestern corner of the island. The first authentically recorded eruption on the island occurred here in 1707. Since that time this cone has been inactive. Saderra Maso[2] has given an extensive account of the various eruptions of Taal, which are

[1] Adams, G. I., Geological reconnaissance of southwestern Luzon, *Philip. Journ. Sci.* 5 A (1910) 57–113.

[2] Saderra Maso, Miguel, The Eruption of Taal Volcano, January 30, 1911. Weather Bureau, Manila (1911) 1–45.

well summarized by Worcester.[3] These include references to a number of eruptions previous to 1707. Some of the eruptions

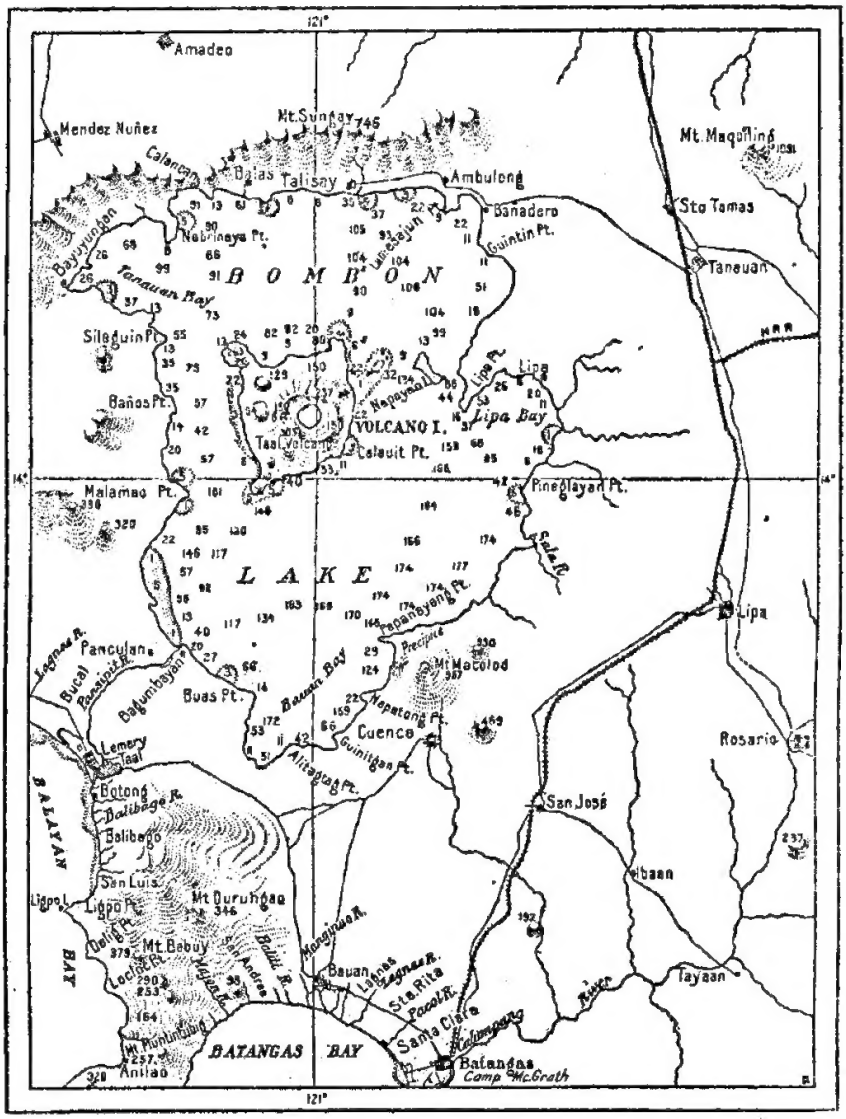

FIG. 1. Lake Bombon and Volcano Island. (Depths and elevations are given in meters.)

have been very violent and have done much damage. The most severe and long continued on record occurred in 1754. The last eruption previous to 1911 was a small one in 1904. This did

[3] Worcester, Dean C., Taal Volcano and its recent destructive eruption, *National Geographic Magazine* 23 (1912) 313–367.

little or no damage to the vegetation on the island. In 1874 there was an eruption during which the entire island was covered with "ashes."

Plate IV is a relief map of Volcano Island previous to the eruption in 1911. The chief change in the physiography wrought by this eruption was within the crater, the center of which is now occupied by a single lake.

FORMER VEGETATION

The only publication that we have been able to find, relating to the vegetation of Volcano Island previous to the eruption of 1911, is a list of 236 species given by Centeno,[4] which he says were collected between the years 1877 and 1879 and were named by Fernandez-Villar. Centeno gives no account of the vegetation, but says that many other plants, mostly grasses and sedges, were growing on the island. The species enumerated are common and widely distributed in cultivated areas, waste places, or second growth forests and are characteristic of cultivated regions at low altitudes in the Philippines. A consideration of the present flora of Volcano Island and that of the neighboring mainland indicates that Centeno's list must have been very incomplete. The first botanist to visit Taal Volcano was Adalbert von Chamisso, of the Romanzoff Expedition (1815–1818), who appears to have left no account of the vegetation of Volcano Island as it then appeared.

No description of the vegetation that existed on the island previous to the last eruption is on record, but a number of Philippine botanists, including Doctors Copeland, Shaw, and Foxworthy and Mr. Merrill, visited the island before the eruption. Their descriptions agree and enable us to form a fair idea of the general type of vegetation.

The main part of the island was covered with a mixture of small trees and grass, the latter being largely *Saccharum spontaneum*. The most prominent tree was a form of *Ficus indica* with small leaves, which was abundant in ravines on the lower slopes of the volcano. On the volcano itself there were scattered tufts of grass, while the rim was bare. The above description of the island agrees very well with photographs that were taken in 1908–1909 and are on file in the Bureau of Science.

The island was subject to very rapid erosion. Radiating

[4] Centeno, J., Estudio Geológico del Volcán de Taal. Madrid (1885) 1–53, *pl. 1–4*.

from the main crater were many very prominent stream beds, which apparently contained water only during heavy rains. These widened rapidly as they approached the shore, forming large deltal fans. The photographs show very clearly that these fans were almost devoid of vegetation. Southwest of and near the main crater is a prominent cone, Mount Tabaro. Judging from the photographs this appears to have been much eroded and quite bare; it is probable, however, that various small clumps of grass were scattered over it. *Plate V, fig. 1,* is a photograph of the main cone of Taal Volcano and Mount Tabaro, taken in 1909. In the center of the picture is the prominent gully running southwestward from the main cone toward Mount Saluyan. The view is toward the north. On the main cone and in the gully there was certainly very little vegetation.

On the low ridges between the dry stream beds the vegetation, grass and trees, came down to the edge of the water in many places. *Plate V, fig. 2,* is a view (1908) of the west side of the island and seems to show that trees predominated in this limited area. The upper part of the main cone appears to be entirely bare. *Plate VI, fig. 1,* also of the west side, shows grass at the edge of the water with most of the trees farther inland. This was taken during the period of activity in 1911 and on the day of the chief eruption which destroyed the vegetation.

Trees predominated in certain localities on Mount Binintiang Malaqui. *Plate VI, fig. 2,* is from a photograph taken of this cone in 1909.

A consideration of the cultural conditions on Volcano Island, previous to the last eruption, throws further light on the nature of the vegetation at that time. On the island there were seven villages. Six of these were located at the northern end and one on the southern coast. Only a small portion of the area was cultivated, but many cattle, carabaos, and horses grazed on the island. The meager description which we have of the vegetation indicates that it was similar to that occurring on the mainland in places where the cultural conditions were similar. This is a common type of vegetation in the lowlands of Luzon in places where the original forests have been removed and consists of a mixture of grass land and small second-growth trees. It can best be designated by the local name *parang,* which has been used in this sense by Whitford,[5] but was erroneously applied

[5] Whitford, H. N., The forests of the Philippines, *Philip. Bur. Forestry Bull.* 10 (1911).

by Vidal [6] to the small second-growth forests that are widespread in the Archipelago. For descriptions of successions on areas from which the virgin forest has been removed see Whitford [7] and Brown and Matthews.[8] Parang is usually the result of human activity, but on Volcano Island volcanic eruptions may have been a contributing factor.

Parang generally originates in the following manner: When the original forests are removed and the land cultivated, but not intensively, grasses—particularly *Saccharum spontaneum* and *Imperata exaltata*, tree species, and weeds make their appearance in large numbers. These are frequently removed by burning, which destroys practically everything except the underground stems of the grasses so that with repeated fires the grasses soon form a solid stand. As the tall, coarse grasses make very poor forage, grass areas are frequently burned to secure young shoots for grazing animals. Wantonly set fires are also frequent. On Volcano island the two latter classes of fires were probably more frequent than those set to clear the land for cultivation. All three classes of fires, of course, produce the same effect.

Where there are no fires, trees occur; and the latter come into the grass when fires are absent for a short period. When the trees begin to form a dense stand, they are again cut down and the above processes are repeated. In this way large areas that are not intensively cultivated become covered with a mixture of trees and grasses. The trees are very different from those of the original forest. They are small, attain a height of about 10 meters, grow rapidly, and are very intolerant of shade. The specific composition is very varied.

In order to obtain an idea of the probable composition of the parang on the island before the last eruption we examined a long strip of the mainland on the western shore of the lake. The principal grass was *Saccharum spontaneum* (talahib). Where the soil was very shallow, the most prominent tree was *Acacia farnesiana* (aroma). On the hills the composition was very complex, but the most numerous tree species appeared to be *Pithecolobium dulce* (camanchíle), *Eugenia jambolana* (du-

[6] Vidal, D. S., Catálogo Metódico de las Plantas Leñosas Silvestres y Cultivadas observadas en la Provincia de Manila (1880) 9, 10.

[7] Whitford, H. N., *Philip. Bur. Forestry Bull.* 10 (1911).

[8] Brown, W. H., and Matthews, D. M., Philippine dipterocarp forests, *Philip. Journ. Sci. A* 6 (1910) 413–561.

hat), *Tabernaemontana subglobosa* (pandacaqui), and *Ficus hauili* (hauili). The shrub *Tabernaemontana pandacaqui* (pandacaqui) and the coarse herb *Blumea balsamifera* (sambong) were also very common. The above plants were probably prominent in the former vegetation on Volcano Island.

Near the small villages perennial cultivated plants such as bananas, bamboo, and fruit trees must have been numerous. Some of the land was probably also intensively cultivated with shorter-lived crops.

The above discussion indicates that parang probably existed on all parts of the island except in the following places: The neighborhood of the villages, where cultivation was fairly intensive; on the steep slopes of the main volcano and Mount Tabaro; and in the stream beds. In some places the growth may have been dense enough to justify its being called a second-growth forest.

DESTRUTION OF VEGETATION

Extensive accounts of the eruption of 1911 have been given by Pratt,[9] Saderra Masó,[10] Worcester,[11] and Martin.[12] These writers agree in saying that the vegetation was completely destroyed. Martin writes:

> Taal Island was devastated, not a blade of grass escaping: trees 15 centimeters in diameter were broken, leaving stumps 0.3 to 0.5 of a meter high; the ends of these stumps were shredded like whisk brooms by the fall of sand and small stones driven by the force of the eruption.

The following description by Masó includes some of the mainland on the western shore of Lake Bombon, or Taal:

> Within the central area which contained 13 barrios and hamlets constructed of bamboo and nipa, the effects are described better by the world 'annihilation' than 'destruction'—human beings, animals, trees, houses, everything was wiped out and covered with a layer of mud out of which only here and there protrudes the trunk of one of the mightier trees!

During the eruption there was no flow of lava and the destruction was not caused by fire. Pratt says:

> The chief agent of destruction and the main cause of death resulting from the eruption was the explosive expansion of the escaping steam, which

[9] Pratt, W. E., The eruption of Taal Volcano, January 30, 1911, *Philip. Journ. Sci. A* 6 (1911) 63–86.

[10] Saderra Masó, M., The Eruption of Taal Volcano, January 30, 1911. Weather Bureau, Manila (1911) 1–45.

[11] Worcester, D. C., *National Geographic Magazine* 23 (1912) 313–367.

[12] Martin, C., Observations of the recent eruption of Taal Volcano, *Philip. Journ. Sci. A* 6 (1911) 87–91.

was violent owing to its movement and suffocating owing to its heat, its burden of mud, and a content of sulphur dioxide.

This blast broke the trees and ground the bark to shreds (*Plate VII, figs. 1 and 2*). Pratt says:

The odor of sulphur dioxide was strong during the eruption and probably this gas or its oxidation product was effective in killing vegetation.

The fall of ash was apparently not particularly heavy. According to Pratt—

The greatest fall of material within the devastated area was on the west slope of the volcano. The maximum thickness of 2 meters noted here occurred where the ash and small fragments had drifted into an old water course. However, the ridges adjacent were all but bare, and therefore an estimate of 20 to 30 centimeters for the average maximum depth of fall for this vicinity is probably reasonable.

Concerning the temperature of the ejecta he writes:

With the exception of the small number of incandescent stones, ejecta from this eruption were apparently not much hotter than boiling water.

The mud appears to have been very injurious to vegetation as is shown by the following statement made by Cox:[18]

While a considerable amount of coarse material fell on the island, the mud that was carried to a distance was comparatively finely divided, and in this respect not greatly unlike road dust. The mud was cool wherever its fall was observed, and it descended in the manner of rain, without violence. Leaves retained only a thin coating on their upper surfaces, yet within a few hours many of them had fallen. Ordinary road dust may fall on plants to any thickness without serious injury.

Cox gives an analysis of ash collected on the island shortly after the eruption. According to this writer, nothing was found that should be injurious to plants. He believed, however, that this analysis did not give a correct idea of the composition of the ash at the time of its fall, and says that there were two possible sources of injuries to plants, namely, sulphuric acid and large quantities of salts of iron, which are often popularly called sulphur. These salts give free acid by hydrolysis when in solution. Worcester lays great stress on injuries done by acid.

Subsequent examination of the island showed that the vegetation was very largely destroyed. In the extreme northern part the destruction was less complete than elsewhere. *Plate VIII, fig. 1*, shows the site of the former village of Pirapiraso just after the eruption. The town is obliterated, while the aërial parts of the vegetation appear to be dead. The ground on the steeper

[18] Cox, Alvin J., The composition of the fine ejecta and a few other inorganic factors of Taal Volcano, *Philip. Journ. Sci. A* 6 (1911) 93–97.

slopes is apparently, not deeply covered with ash. Near the former villages in this northern region a number of clumps of bamboo of two different species and bananas of three varieties have regenerated from the old root stocks. Both of the bamboos, *Bambusa blumeana* and *B. vulgaris*, are introduced species that in the Philippines are not known to spread except through the agency of man. The last statement also applies to two of the varieties of banana. The influence of the bamboos and bananas on the invading vegetation, therefore, should be very slight. The number of clumps of bamboos and bananas, that survived indicate, however, that the root systems of a number of trees might likewise have remained alive and that some of the trees at present on the island may have sprung from these. This is particularly true, since it is characteristic of many parang species to spring up from the ground after the aërial parts of the plants have been killed. A few individuals of the following species of trees appear to have survived the eruption:

Trema orientalis.
Moringa oleifera.
Pithecolobium dulce.
Semecarpus cuneiformis.
Ficus indica.
Eugenia jambolana.
Ceiba pentandra.
Cratoxylon blancoi.
Sterculia foetida.
Annona reticulata.

It is almost certain that other species survived; although this cannot be demonstrated, as after a few years root sprouts are not easily distinguished from plants produced by seeds. It is only when an exceptionally large stem, broken off above ground, has regenerated or where, as in the case of the bamboos and bananas, no seeds are produced, that we can be sure a plant has survived the eruption. In the vicinity of the village on the southern coast of the island no bamboos or bananas and probably no trees have regenerated. In conclusion we may say that, with the possible exception of the extreme tip of the peninsula at the southwestern corner, the destruction of the vegetation was probably complete on the southern and central parts of the island. Near the northern coast many root systems and probably some seeds escaped.

REVEGETATION OF CLEARED AREAS

Before describing the revegetation of the island, it may be of interest to discuss briefly the vegetation that invades areas from which forests have been removed and the land not cultivated.

In northern Negros large areas of virgin dipterocarp forests on the banks of Himugaan River have been logged by a lumber

company. The removal of the main canopy has resulted in the destruction of the undergrowth. The land was very quickly invaded by a small second-growth forest of a type that is entirely different from the original vegetation. *Trema orientalis* (anabion) is by far the most prominent tree, and in many places it forms practically pure stands. Associated with it are, however, a large number of other second-growth tree species.

Also on Mount Mariveles in Bataan Province, Luzon, a large area of virgin dipterocarp forest has been destroyed by logging. The ground was very quickly invaded by a second-growth forest similar to that in northern Negros, except that here the principal tree species is *Homalanthus populneus* (balanti). In neither of the above regions was a second-growth forest preceded by grass. On Mount Mariveles no species, other than trees, was prominent in the early stages of invasion. In northern Negros a wild banana was abundant, but no small species was conspicuous.

The succession in these two areas appears to be typical of that which occurs in similar places in the Islands in general. For a more extensive discussion of cleared areas see Brown and Matthews.[14]

The invasion of cleared areas may be summarized as follows: When forests are removed and the land not cultivated the ground, within one or two years, is covered by a second-growth forest in which, frequently, one species is much more prominent than any other. The dominant species invariably have a rapid rate of growth.

Cultivation that is not intensive usually results in the formation of grassland or parang. This process has already been discussed.

REVEGETATION OF VOLCANO ISLAND

The progress of revegetation on Volcano Island has been very different from that described above for lands cleared of vegetation and afterward not cultivated. The chief invading species have been grasses, and revegetation has been so slow that in most parts of the island the ground, after nearly six years, is only sparsely covered.

Our knowledge of the early stages of revegetation of Volcano Island is due to Gates,[15] who visited the volcano in October and December, 1913, and in April, 1914.

[14] Brown, W. H., and Matthews, D. M., *Philip. Journ. Sci. A* 6 (1911) 413–561.

[15] Gates, Frank C., The pioneer vegetation of Taal Volcano, *Philip. Journ. Sci.* 9 (1914) *Bot.* 391–434, *pl. 3–10.*

Gates gives a very short account of the progress of revegetation during 1911 and 1912. He did not visit the island until October, 1913, and does not give his source of information, the reliability of which is questionable as we know of no trained botanists who visited the Island during that period and the remembrance that untrained men have of their casual observations is likely to be very poor evidence on a subject of this kind.

In October, 1913, Gates found a wide strip of vegetation across the northern end of the island and also some vegetation at the extreme end of the peninsula at the southwestern corner. In many places, even in the above regions, the vegetation was very scanty. The remainder of the island was without plants. The vegetation seems to have consisted largely of a tall, coarse grass, *Saccharum spontaneum*, although trees and other plants were present in considerable numbers. The growth of *Saccharum* was apparently fairly dense in certain localities at low elevations. In describing these Gates says:

> At lower elevations the bunches occur nearer together until a fairly dense stand occupies the lower slopes, yet even in these places the great growth activity has not yet succeeded in obliterating the bunch-grass habit and covering the ground.

The early appearance of vegetation in the northern part of the island is probably connected with the fact that here the effects of the eruption were less severe than elsewhere.

Gates found no evidence to show that any of the grass had sprung from clumps existing previous to the eruption. His first visit was two and a half years after this event, so it is hardly to be expected that any such sign would have been noticeable. Probably most of the grass in this region was killed, but it seems quite possible that scattered clumps may have survived as this grass has characteristic, deep-seated rhizomes. *Saccharum* seeds during both monsoons. Therefore, if all of the first plants of *Saccharum* grew from seed coming from the mainland, we would hardly expect it to form such dense stands in a limited area and to have been so circumscribed in its early distribution. In localities where Gates found *Saccharum* occuring as scattering clumps in 1913 and 1914 this plant does not even now form dense stands nor do the individual clumps appear to have reached mature size. This would indicate that the dense stands of grass that Gates found in 1913 and 1914 would have required more than three years to develop from seed. Such clumps as survived may very well have been reduced in size to small tufts. Unfortunately the only observations on the revegetation of Taal

previous to 1913 were made from a distance of many kilometers, whereas in our experience we have found that even at a distance of less than a kilometer it is impossible to tell whether or not small tufts of grass or other small plants are present on an area.

When Gates visited the island in April, 1914, the vegetation had spread over a much larger area than it occupied in 1913. Most of the land on the part of the island north of the main crater supported plants, while vegetation had spread over the whole southwestern peninsula as far as the top of Mount Saluyan. A narrow strip of vegetation had also appeared along the eastern coast. In the area invaded between October, 1913, and April, 1914, the vegetation was apparently very sparse on the latter date. Vegetation was also still scarce on much of the land that supported plants in 1913.

GRASSES

Until now (January, 1917) by far the most prominent invading species has been *Saccharum spontaneum* (talahib), which is scattered all over the island. In a few limited areas in the northern part it forms dense stands. Elsewhere it occurs as scattered clumps. On the lower gentle slopes these clumps are fairly large and well developed. In very favorable situations in the Philippines *Saccharum* may reach a height of 4.5 meters, but on Volcano Island it does not attain this size, being rarely more than 3 meters in height. Where it occurs as scattered clumps, it is even smaller than this. Except in very limited areas it is easily possible to walk between the individual clumps, and in most places the distance between clumps is considerably greater than the height of the grass. *Plate VIII, fig. 2,* is from a photograph taken near the shore, west of a point between the two old craters on the western side of the island. It gives a good idea of the average development of *Saccharum.* On the steep slopes of the main cone and Mount Tabaro, in the dry stream beds, and on the deltal fans *Saccharum* appears only as scattered, dwarfed tufts, which owing to the rapid erosion lead a very precarious existence. *Plate XIV, fig. 1,* shows a wide deltal fan with a narrow stream bed extending through it. These fans are almost devoid of vegetation. Over long stretches in the central and southern part of the island there is very little conspicuous vegetation other than *Saccharum.*

Near the coast in some of the open places between the widely separated clumps of *Saccharum* there are various scattered plants of small grasses and sedges. The most conspicuous of these

grasses have a running habit. These grasses and sedges are so small and scattered that even at a short distance they are not noticeable and the ground that they occupy appears to be quite bare. An exceptional development of them is shown in *Plate VIII, fig. 2.*

In the extreme northern part of the island and at the tip of the peninsula, which projects from the southwestern corner, there are some very steep slopes. In these places another tall grass, *Themeda gigantea,* predominates; and erosion is apparently not very rapid at the present time. *Themeda* is confined largely to the various steep slopes, which are at a considerable distance from the crater, and in such places it makes a better growth than *Saccharum.* At the present time *Themeda* occurs mostly in dense stands. It is most prominent on Mount Binintiang Malaqui and the neighboring horseshoe ridge, Mount Balantoc. In both of these places the stands are frequently so dense that it is extremely difficult to walk through them.

In a limited region in the northeastern corner of the island, between Mount Bignay and Mount Ragatan, and at the northwestern corner near the former village of Pirapiraso, *Imperata cylindrica,* a much smaller grass than either *Saccharum* or *Themeda,* covers the ridges and some of the slopes. The valleys in this region are occupied by *Saccharum. Imperata cylindrica* is a very common grass on the mainland around Lake Bombon, and so it seems surprising that its distribution on Volcano Island should be so limited. This is particularly so, because *Imperata* usually occurs on dry ground. On the parts of Volcano Island where *Imperata* and *Saccharum* occur together, they occupy the same relative positions that they usually do on the mainland; that is, *Imperata* in the drier and *Saccharum* in the moister situations. However, in other parts of the island *Saccharum* occurs in situations that appear to be dryer than those occupied here by *Imperata.*

Another case of a peculiar distribution of a grass is afforded by *Miscanthus sinensis.* This tall grass usually occurs at high altitudes in places where the soil is moist and the evaporation low. In such situations it frequently forms extensive dense stands, which result from fires in the same manner as do those of *Saccharum spontaneum* at low altitudes. On Volcano Island this grass is mainly confined to small patches, which occur on the sides of the ravines and are frequently only a few meters above sea level. The total area occupied by this grass is very small.

The very open nature of the stand of grass on most parts of the island is certainly not due to competition and apparently not to a lack of seed. *Saccharum, Imperata,* and *Miscanthus* have adaptations for the distribution of the seed by wind, and the first two certainly produced large quantities of seed on the island as early as three years ago.

The failure of grass to produce dense stands even in most places where it occurred as scattered patches in 1914 would indicate unfavorable environmental conditions. This view is supported by the reduced height of the clumps of *Saccharum.*

TREES

Trees are very scarce except in limited areas near the northern coast and at the extreme tip of the peninsula that extends from the southwestern corner. Even in these localities grasses are very much more prominent than trees Elsewhere the trees occur only as very widely separated individuals or as clumps of two or three individuals. *Plate XI, fig. 1,* is from a photograph taken at the northwestern end of Mount Balantoc and shows an exceptional development of trees.

The only area in which trees predominate is on the northern slopes of Mount Pirapiraso, at the northwestern corner of the island, where the second-growth forest reaches its greatest development and covers more than half of the area, the remaining space being largely occupied by grass.

The specific composition of the tree flora of Volcano Island is extremely varied when the small number of the individuals is considered.

The most abundant species is *Acacia farnesiana* (aroma), which is scattered over the whole island except on the main cone and Mount Tabaro. This plant is very common on the mainland around Lake Bombon, and in the Philippines generally it is prominent in the early stages of invasion of grasslands by trees. Its success in the latter situation is due to its ability to regenerate after the aërial portions of the plant have been killed by fire. In view of this habit and its present prominence on the island it seems not unlikely that a considerable number of plants of this species may have escaped destruction during the eruption of 1911. On the other hand the seeds of aroma are inclosed in a woody pod which floats so that it may readily have been washed ashore; in which case, however, we must account for its distribution in places distant from the shore. The method by which

it has been distributed all over the island is not evident, as it is apparently not adapted to be eaten by birds or for wind dispersal.

The next most prominent tree is a small variety of *Ficus indica*. In favorable situations on the mainland this tree reaches a fairly large size, in many cases being 15 meters in height. The trees on Volcano Island are smaller and the tallest probably average about 7 meters. This was about the height of the largest individuals on the island previous to the eruption of 1911.

In the northern part of the island trees of this species were observed that had apparently sprouted from old stumps. *Ficus indica* is well known as a tree with a very irregular habit of growth. This plant, like most of the irregular-growing figs, is very tenacious of life; and it seems probable that its presence in large numbers is due, in part at least, to individuals that were not destroyed by the eruption, as *Ficus indica* is not abundant on the mainland. However, the seeds of this plant might be readily dispersed by birds. *Ficus indica* is particularly prominent on the main crater, as it is practically the only tree species that occurs on this cone. However, the number of individuals found here is small, and they are confined largely to the ravines on the lower slopes. Within the crater *Ficus indica* is represented by a single specimen on the northern wall, while several individuals were found at the edge of the crater.

Next to the above the most prominent tree species are:

Eugenia jambolana (duhat).
Trema orientalis (anabion).
Tabernaemontana subglobosa (pandacaqui.)
Morinda bracteata (tumbong aso).
Pithecolobium dulce (camanchile).
Antidesma ghaesembilla (binayuyo).

It will be seen that this list of common species is very similar to that previously given for the mainland. The seeds of all of these trees are distributed by birds.

The tallest trees and the densest stands of tree species are found near the northern shore. The presence of plants that survived the eruption and better soil conditions undoubtedly account in part for the greater density of tree vegetation found here. Some of the most prominent tree species in this region escaped distribution during the eruption, as is shown by the presence of individuals growing from old stumps. This has been observed in the case of *Ficus indica, Eugenia jambolana,*

and *Trema orientalis;* and, as we have seen it may very well have been true of *Acacia farnesiana.*

All of the trees of any prominence occuring on the island are characteristic of parang. They are small species, which have a rapid rate of growth and mature early. *Acacia farnesiana* and *Tabernaemontana subglobosa* might perhaps be as well termed shrubs as trees, but for convenience we have used the latter term. The small size of the trees can be seen from the data given in Table I, which is compiled from Merrill's Flora of Manila.[16]

TABLE I.—*Mature height of common trees on Volcano Island.*

Species.	Height in meters.
Ficus indica	4–12
Acacia farnesiana	2–4
Eugenia jambolana	4–15
Trema orientalis	5–8
Tabernaemontana subglobosa	2–5
Morinda bracteata	3–10
Pithecolobium dulce	5–18
Antidesma bunius	4–10
Antidesma ghaesembilla	4–10

Owing to the rapidity with which most of the tree species mature, large quantities of seed have already been produced on Volcano Island. Many of the species frequently produce seed when much less than 1 meter in height. We have seen that most of the prominent trees have fruits that are readily scattered by birds. As an illustration of the facility with which seeds are distributed in this way, we may mention a case observed in a clearing of 0.25 hectare on Mount Maquiling at an altitude of 450 meters. In a few months the ground was covered by a second-growth forest consisting largely of *Trema orientalis.* The nearest observed plants of this species were about 3 kilometers distant and approximately 250 meters lower in elevation. There were certainly few if any individuals nearer than this, as the clearing was made in the center of the virgin forest, and *Trema* is so intolerant of shade that it will not grow under the cover of even the most open second-growth trees.

It seems from the above that enough seeding must have taken place on Volcano Island to produce a denser tree vegetation than that which now exists. Moreover, the scarcity of any particular species or of trees in general is certainly not due to competition,

[16] Merril, E. D., A Flora of Manila. Manila (1912) 1–490.

but apparently must be referred to unfavorable external conditions. These factors will be considered later.

SHORE VEGETATION

One of the most interesting features in the distribution of plants on the island is that of *Ipomoea pes-caprae*. This plant is a spreading vine, which usually forms a part of the strand formation on sea beaches. It occurs as occasional patches on the mainland shore of Lake Bombon where it is sometimes mixed with *Canavalia lineata*, a leguminous species of similar habit. While the leaves of *Canavalia* are compound and those of *Ipomoea* are simple, nevertheless the texture and the color of the leaflets of *Canavalia* and of the leaves of *Ipomoea* are so similar that it is only by the flowers that the two plants can be readily distinguished at a distance. These two plants occur together in scattered localities along the shore on all sides of Volcano Island, but they are more conspicuous on the slopes inland from the southern and southeastern shores. They have apparently grown over the ash on the southern coast to an altitude and distance as limited only by the period during which growth has taken place. Both have reached a vertical height above the lake of more than 50 meters, while *Ipomoea* is prominent more than 0.25 of a kilometer from the coast. Over large stretches of the lower ridges near the coast *Ipomoea* forms a thick carpet between the clumps of *Saccharum*. As the *Saccharum* becomes denser, it will probably replace the *Ipomoea;* as along the northern coast, where the growth of *Saccharum* is thicker, *Ipomoea pes-caprae* is confined to the beach and does not occur inland.

Ipomoea is particularly abundant near the southern and eastern coast and on the peninsula that extends from the southwestern corner and to a less extent around the base of Mount Binintiang Malaqui. Except in the two last-named regions *Ipomoea* and *Canavalia* are represented on the western coast by only a few scattered plants. This is apparently due to the presence of numerous wide deltal fans on this side of the island. In *Plate IX, fig. 1, Ipomoea* is shown growing near the water's edge, but more abundantly on the more elevated ground where it is mixed with *Saccharum*. *Ipomoea* grows on the mainland in an area made swampy by fresh-water springs. This distribution is apparently not connected in any way with a high salt content of the soil.

Gates [17] in describing this vegetation in 1914 says:

> *Canavalia* tends to extend inward away from the water to a very much greater extent than *Ipomoea*, which is usually confined to the shore. Exceptions occurred on the lava ridges of Mount Binintiang Munti, where *Ipomoea* spread a considerable distance from the shore, and in a few places on the eastern side of the island, where unaccompanied with *Canavalia*, *Ipomoea* spread back several meters and attained an altitude of about 30 meters on the mud slope.

FERNS

At low altitudes there are many ravines from 2 to 3 meters in depth and less than 1 meter in width. On the northern slopes these ravines have developed into veritable cañons, often with perpendicular walls many meters in height. In these there is frequently a considerable development of a fern flora and a few species of mosses and hepatics. The most prominent ferns are:

Acrostichum aureum.
Ceropteris calomelanos.
Nephrolepis biserrata.
Pteris vittata.
Pteris quadriaurita.
Onychium siliquosum.
Odontosoria chinensis.
Blechnum orientale.
Cheilanthes tenuifolia.
Adiantum philippense.

AQUATIC VEGETATION

We have made no special study of the aquatic vegetation around the island. Our knowledge of this was obtained from observations made while walking around the whole shore of the island, except an inaccessible portion at the base of Mount Binintiang Malaqui, and while bathing at a number of different points.

On some of the rocks there is a considerable growth of *Cladophora*, but this was the only attached vegetation observed with the exception of two small plants of *Vallisneria gigantea*, the roots of which were half exposed by the action of the waves. Along the northern shore were found a considerable quantity of broken *Vallisneria* and a single piece of *Ceratophyllum demersum* that had been cast up by the waves. Occasional plants of the floating aroid *Pistia stratiotes* were observed at different places along the shore.

ASSOCIATIONS

The vegetation of Volcano Island is not readily divided into formations or associations. This is a natural result of similar external conditions over the whole area and the scarcity of vegetation, which consists, either entirely of *Saccharum*, or of

[17] Gates, F. C., *Philip. Journ. Sci.* 9 (1914) *Bot.* 319–434.

a heterogeneous mixture in which many plants occur in situations very different from those in which they are usually found. The occurrence of patches of *Miscanthus*, a typical high-mountain grass, near the sea level is a conspicuous example. Equally striking is the growth of *Ipomoea* mixed with *Saccharum* at considerable distances from the shore. The scattered patches of *Miscanthus* in an unusual situation can hardly be regarded as constituting an association. The same might be said of *Ipomoea* that is growing between the clumps of *Saccharum*. The scattered plants of *Ipomoea* and *Canavalia* that are found on the beach can hardly be considered as a strand formation. Certainly there is little similarity between the growth composed of these species on Volcano Island and the normal strand formation as found on the sea beach.

The great preponderance of grass on the island seems to justify the classification of the vegetation as an invasion by a grass formation. The principal association of grass is certainly *Saccharum spontaneum*. In some places on the steep slopes *Themeda gigantea* occurs in stands that are pure enough to justify its being classed as a separate association. On the mainland both *Saccharum* and *Themeda* constitute very definite associations.

The tree flora is so scattered and is composed of such a heterogeneous mixture of different species that it is impossible to recognize any clear divisions, and the whole can best be regarded as an early stage of the invasion of grassland by a second-growth forest formation. The prominent species are all small, and all are characteristic of the early stages of the invasion of grassland or other open areas by trees in many parts of the Philippines. Second-growth forests should give place to the tall dense forests characteristic of this region. In this process there must be a number of stages or successions. Our knowledge of these successions is very fragmentary at present, so that the different stages cannot be described. However, on Taal there seems to be no indication of a second stage, as all the species of any prominence are characteristic of the very first stages of the invasion of grassland or other open areas by second-growth forest. Gates [18] divides the invading trees and shrubs into two formations. One of these he calls the parang, or shrub-small-tree, formation and the other, the low-altitude tree formation. In each of these he recognizes a single association. The first is the

[18] Gates, F. C., *Philip. Journ. Sci.* 9 (1914) *Bot.* 391–434, *pl. 8–10.*

parang association and the second, the *Bambusa-Parkia* association. The latter according to Gates succeeds the former.

Gates says very little about his reasons for making this division, which, with modifications, is an attempt to follow Whitford [19] in his description of a very different type of vegetation in an area that unfortunately was not visited by Gates. The division as applied to Volcano Island does not seem to be justified, and the choice of names is unfortunate.

While Gates does not so state, it seems evident that he did not intend to imply that his *Bambusa-Parkia* association was the same as that described by Whitford, but he simply used the term in a very broad sense to denote lowland forests. Whitford's [20] *Bambusa-Parkia* formation, described from the base of Mount Mariveles, consisted of a mixture of bamboo and trees and was regarded as a climax formation. Since Whitford's paper was written, a large area of dipterocarp forest in this region has been logged by a lumber company and has changed to the *Bambusa-Parkia* type.[21] The characteristic bamboo *Schizostachyum mucronatum* (boho), a native species smaller than *Bambusa blumeana,* occurred as scattered clumps in the dipterocarp forest. After the forest was logged, these spread until in many places *Schizostachyum* formed almost pure stands. The large trees of which *Parkia* is a representative are, for the most part, relics of the former forest, which were left because they were not of sufficient value to be removed. Only two of the trees mentioned by Gates as belonging to his *Bambusa-Parkia* association are given by Whitford in his list of the eighteen prominent trees in this association.

The bamboo of Gates's association is *Bambusa blumeana,* which has regenerated from rootstocks that were present before the eruption and were not killed by the covering of mud and ashes. In the Philippines this bamboo is a cultivated form, which rarely, if ever, forms new clumps except where planted, and therefore it cannot be considered as part of an invading association.

Gates's *Bambusa-Parkia* type is certainly very different from that described by Whitford. Gates gives such a brief description that his conception of it is not clear, and we are unable to identify it with any of the usual types found in the Philippines. When Gates mentions the occurrence of this type, he evidently

[19] Whitford, H. N., *Philip. Journ. Sci.* 1 (1906) 373.
[20] Whitford, H. N., loc. cit.
[21] Brown, W. H., and Mathews, D. M., *Philip. Journ. Sci. A* 9 (1914) 457.

refers not to what he considers a typical development of it, but to the presence of scattered individuals representing it. The plants listed seem to be a heterogeneous collection whose different members would not be prominent in the same habitat.

We have shown that the name "parang" is properly applied to a mixture of grass and second-growth trees. In his use of this term Gates followed one of Whitford's earlier papers in which the latter in turn followed Vidal.

Gates described three moist-ground, or marsh, associations of grasses and a "back strand association" of *Sesbania*, all occurring along the coast, apparently on the deltal fans, or at the foot of bluffs. Owing to the rapid erosion on the island such plants would necessarily lead a very precarious existence. As we found no traces of such vegetation, it seems probable that they had been either washed away by water from the lake, or destroyed by floods on the deltal plains. The chief plants of these associations were found only as widely scattered individuals. For example, Gates describes a *Sesbania* strand association as occurring in several localities and as rapidly invading the *Ipomoea pes-caprae* association. In 1916–17, we found only a single seedling of *Sesbania* on the island.

REGIONAL DESCRIPTION

The discussion of the vegetation that existed on the island in 1913 and 1914 is based on Gates's [22] description and pictures. Owing to a lack of exactness in his statements it has been difficult, in some cases, to interpret Gates's account. Thus he says (p. 395):

> By December, 1913, vegetation was quite well established on the northern side of the island to an altitude of about 175 meters. If consisted largely of grass—entirely dense at low altitudes, * * *.

What he means when he says "entirely dense" is not evident, as *Saccharum* is the principal grass and in describing the "Saccharum consocies" he says that even at lower elevations the growth activity has not "succeeded in obliterating the bunchgrass habit and covering the ground." *Saccharum* is usually about as high as a man and is normally so dense that it is exceedingly difficult to force a way through it, even for a short distance. In January, 1917, the growth of *Saccharum* in the northern part of the island was so open that, except in very limited areas, one could readily pass in any direction over the whole region and along the shore of the lake without the slightest

[22] Gates, F. C. *Philip. Journ. Sci.* 9 (1914) *Bot.* 391–434.

difficulty. When Gates mentions the occurrence of tree vegetation he evidently refers in almost all, or in all, cases to a distributional stage in which the trees are scattered.

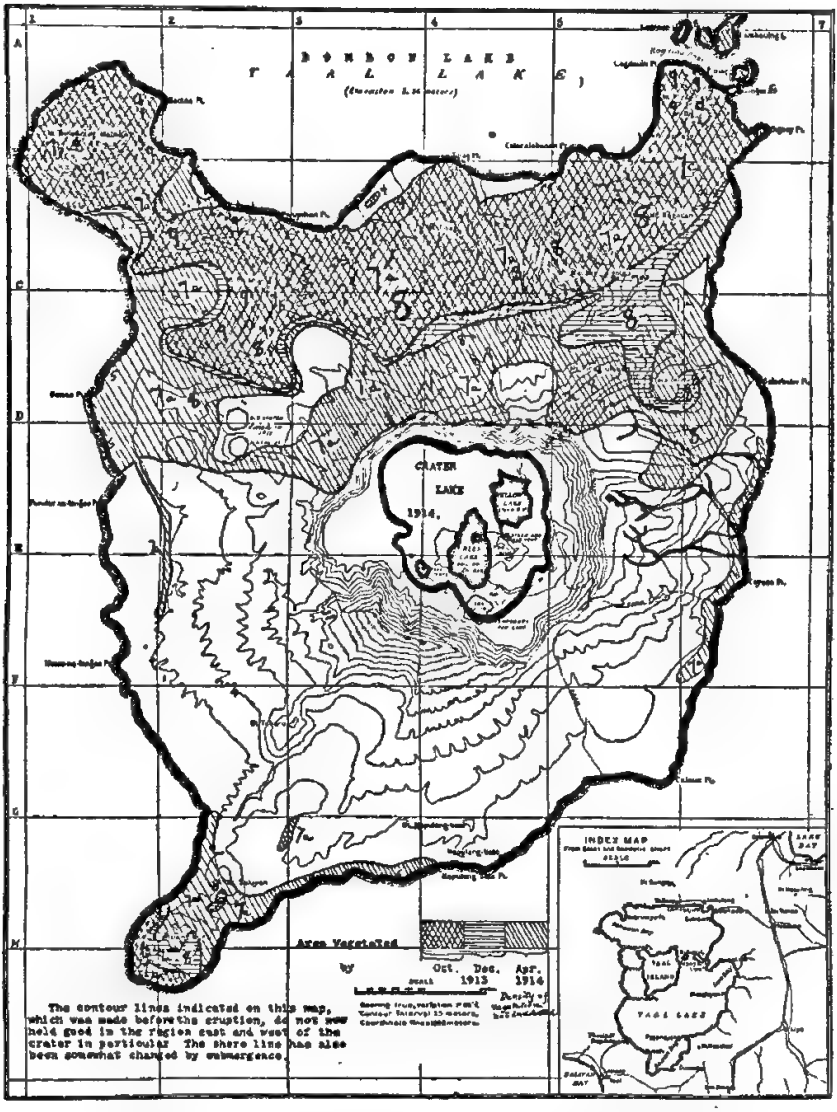

FIG. 2. Areas on Volcano Island invaded by plants in 1913 and 1914.

While some of Gates's statements are inexact, we believe that with the help of his pictures and a knowledge of the present vegetation of the island we have interpreted them correctly. *Text fig. 2*, a map taken from Gates's paper, shows the areas in

which vegetation occurred in 1913 and 1914. The relative abundance of the vegetation in different regions is not indicated on the map.

As the revegetation began at the northern end of the island, we will begin our discussion with that area.

The northwestern corner of Volcano Island is formed by Mount Binintiang Malaqui whose summit is more than 250 meters in height, which with the exception of the southwestern rim of the crater is the highest point on the island. The slopes of this peak are very steep, and the valleys are rather shallow. Gates found that on the greater part of the slopes and always on the steeper ones *Themeda gigantea* occurred as open well-spaced clumps. On the sides of the valleys bushes were frequently present, while on the northwestern side, away from the crater, trees from 4 to 5 meters in height were found. The chief change since Gates's visit seems to be that the *Themeda* has become much thicker and in many places forms solid stands, while the trees have increased in size and probably also in number. The predominant vegetation is *Themeda.* Mixed with this is a much smaller amount of *Saccharum,* while trees are few and much scattered. *Plate IX, fig. 2,* shows Mount Binintiang Malaqui from Gunao Point. The dark spots are the trees. The number of trees shown here is very similar to that found on the northern slopes. A comparison with *Plate VI, fig. 2,* shows that trees are very much less prominent than before the eruption.

Southeast of Mount Binintiang Malaqui is a prominent horseshoe ridge, Mount Balantoc. On the northern and northeastern slopes of this mountain Gates found trees mixed with *Themeda gigantea.* In this region *Themeda* and *Saccharum* now form dense stands, while trees are prominent in the ravines. The trees are present in sufficient number to give character to the vegetation, but nowhere do they form stands dense enough to kill the grass. The vegetation can best be classified as parang in which the grass covers at least twice as much area as the trees. *Plate X, fig. 1,* is from a photograph by Gates and shows Mount Balantoc in the foreground. Gates evidently meant only that woody plants were prominent when he said that this region "was largely wooded." The remainder of Mount Balantoc is now covered with an open growth of *Saccharum* while trees are prominent in the ravines. *Plate XI, fig. 1,* is from a photograph taken on the southern slope of the northwestern end of this mountain. The spacing of the *Saccharum* and the number of trees are shown very clearly. In the distance the grass appears

to be much denser than in the foreground; this appearance is deceptive, as in reality the grass is no thicker on any part of the slope than in the foreground. *Plate X, fig. 1,* is from a photograph taken by Gates in April, 1914, of another portion of Mount Balantoc where the vegetation at present is very similar to that shown in *Plate XI, fig. 1.* A comparison of these two views indicates that the revegetation since 1914 has not proceeded as rapidly as would be expected if the vegetation seen by Gates in the northern part of the island had been entirely new.

The low divide separating Mount Balantoc and Mount Binintiang Malaqui is covered by an open stand of *Saccharum* and scattered trees. Bananas and bamboos are present in the vicinity of the old villages. All of the bamboos have probably regenerated from old rootstocks. One of the varieties of banana appears to be spreading to a slight extent. Plants of *Saccharum* and trees are more numerous than when Gates visited the island, but as might have been expected there is no evidence of any increase in the number of clumps of bamboos. It is interesting that in October, 1913, Gates found only three clumps of bananas and no clumps of bamboos. "In April, 1914, bananas were fairly abundant and indicated quite well the positions of many of the former houses," while bamboos were prominent. This would indicate that bananas and bamboos could remain alive for a considerable period of time without showing any activity above the ground.

In 1914 the vegetation was fairly well developed in the area partly inclosed by Mount Balantoc. This is now covered by an open growth of *Saccharum* and scattered trees.

Plate XI, fig. 2, is a view of the northwestern part of the island from the junction of Mount Pinag-ulbuan with the crater rim. Mount Balantoc and Mount Binitiang Malaqui appear in the distance.

The northeastern corner of the island is formed by a peninsula containing Mount Pirapiraso and Mount Bignay. In this region Gates found the densest vegetation that occurred on the island in 1914. His photograph of Mount Pirapiraso and Mount Bignay seems to show that here grass predominated, while scattered trees were fairly abundant. The grass, however, had apparently not reached its normal density, as Gates in discussing areas covered by *Saccharum* says that even on low slopes the bunch-grass habit had not been obliterated. At the present time the ground except in a few localities is densely covered by a mixture of grass and trees. The trees occupy about as large

an area as the grass, and on the north slope of Mount Pirapiraso the trees cover more than 50 per cent of the ground. A comparison with Gates's pictures indicates that trees are now more numerous in this region than in 1914. Their greatest development is in the ravines. Scattered clumps of bamboos also occur in this locality. The latter are apparently the same ones that were seen by Gates. In this region the second-growth forest is better developed than on any other part of the island, and here we find the most complex vegetation. Many species are found in the immediate vicinity of Pirapiraso that were not observed elsewhere on the island. The thickets are so dense in many of the ravines and on some of the northern slopes, that it is difficult to penetrate them, the bushes and small trees being often overgrown by a tangled mass of herbaceous and woody vines.

On the divide between the former towns of Pirapiraso and Bignay Gates found a stand of *Imperata cylindrica* and *Saccharum spontaneum*. Scattered trees were also present. *Saccharum* has apparently invaded much of the area occupied by *Imperata*, a much smaller grass, and is at present much more prominent than the latter.

Mount Ragatan runs diagonally across the base of the northeastern peninsula. Gates found this rather densely covered with grass, shrubs, and small trees. The grass on the northern slope is now fairly dense. Trees are numerous in the ravines, but scarce on the ridges. On the eastern and western slopes the grass is well developed, but numerous bare strips running with the slope make it fairly easy to penetrate. On the southern slope the vegetation is largely *Saccharum*, which is still open enough to allow one to pass through it readily.

Southwest of Mount Ragatan is a crescent-shaped ridge, Mata-as-na-golod. In October, 1913, the vegetation on this mountain consisted almost entirely of *Saccharum* in clumps and extended about two-thirds of the way to the top. By December it had reached the top. The vegetation in 1917 still consists almost entirely of *Saccharum*, which has not yet formed a stand of its normal density; although on the northern slopes the bare ground occurs only as numerous patches, which usually appear much smaller than a clump of *Saccharum*. On many of the ridges on the southern slopes there are considerable areas that are almost bare. This mountain is the prominent peak in Plate *XII, fig. 1*. It is not clear what Gates meant when he said that a closed stand of *Saccharum* occurred on the western, eastern, and northern

slopes in April, 1914. In discussing the general distribution of *Saccharum* (p. 410) he gives the impression that nowhere did it form stands of normal density.

In the region between Mounts Balantoc and Mataas-na-golod there are two prominent dry stream beds, which in 1914 contained a few plants of *Phragmites*. They are now covered with scattered clumps of *Saccharum*. The remainder of this area contained almost nothing but grass in October, 1913, but by April, 1914, many shrubs were present. *Plate X, fig. 3*, is a view taken by Gates in October, 1913, from near the crater rim and looking northward toward Mount Tibag in the center of this area. The vegetation on the north-central region still consists very largely of *Saccharum spontaneum*, which even now in most places forms a very open stand.

The regions that we have discussed constitute the area in the northern part of the island on which plants occurred in October, 1913. This area is shown in *text fig. 2*, a map taken from Gates's paper, and may be defined as being bounded on the south by a line starting slightly south of Bignay, running south of Ragatan and Mataas-na-golod, then slightly southwest and around the southern end of Mount Balantoc. *Plate XI, fig. 2*, and *Plate XII, fig. 1*, from photographs taken in October, 1916, show nearly all of this region with the exception of the northeastern peninsula and also some of the area nearer the crater. It will be seen that in most places there is a considerable amount of bare ground, while grass is everywhere the predominant element in the vegetation.

By April, 1914, the area containing plants had been considerably extended, plants being found clear to the rim on the northern side of the main crater and somewhat south of the old craters, which are shown on the map east and west of the northern end of the main crater. In 1914 the vegetation in this area was very sparse, and even at the present time the bare ground is many times greater in extent than that covered by plants. The most prominent plant is *Saccharum*, while trees and shrubs are very scarce. In October, 1913, there was a sparse development of plants at the extreme tip of the southwestern peninsula. By April, 1914, this vegetation had spread to the summit of Mount Saluyan, which is about the point where the peninsula branches off from the mainland. This vegetation was apparently very scanty; and even now trees are scarse, while the grass occurs as widely spaced clumps except in very limited areas where *Themeda* forms dense stands on steep slopes. In *Plate XII, fig.*

2, the trees are shown as dark spots. Although the grass forms a very open stand this fact is not evident in the picture, which was taken at too great a distance to show the spacing. The grass consists almost entirely of *Saccharum* except on the steepest slopes at the end of the peninsula where *Themeda* predominates. Over much of this area *Ipomoea pes-caprae* is found between the clumps of *Saccharum* and is particularly well developed at the end of the peninsula, where it grows over the top of the highest ridge.

In 1914 there was also a slight development of vegetation running along the southern shore to a point slightly west of south of the center of the main crater, while along the middle region of the eastern shore there was also a slight development of vegetation. In 1914, however, most of the central and southern parts of the island were without plants.

At the present time the vegetation has spread over the whole island, but is very scanty in the places where there was not a considerable development in 1914. The vegetation characteristically consists of very widely spaced clumps of *Saccharum* with a few scattered trees. *Plate XIII, fig. 1,* which was taken from Calauit Point, looking northwest, gives a very good idea of the density of the vegetation over the southern and central parts of the island. *Plate XIII, fig. 2,* shows both sides of the prominent dry stream bed extending southwest from the crater. On the right are seen the slopes of Mount Saluyan. This shows the character of the vegetation in the southwestern region very clearly. The numerous clumps are *Saccharum*, while the six larger and darker ones are trees. The vegetation is very similar over the whole of the recently invaded area, except that in many places near the southern and southeastern coasts *Ipomoea* has grown inland to a considerable distance between the clumps of *Saccharum.* This development is greater near the western end of the southern coast, where *Ipomoea* is very conspicuous more than a quarter of a kilometer inland.

The dry stream beds and deltal fans are everywhere almost entirely barren. These are most prominent on the western side of the island, particularly that part west and southwest of the main crater where they occupy practically the whole area. This region is particularly bare. *Plate XIV, fig. 1,* shows a view from Pandac-na-lo͂ngos Point (*text fig. 2*) west of the main crater, and looking southeast with the main crater in the left of the picture. Most of the view is occupied by a large deltal fan through which there extends a narrow stream bed. The barren-

ness of the area is very evident. In the distance there are scattered clumps of *Saccharum*. On the right is seen a low divide, which separates this fan from the prominent one north of Mount Tabaro. The latter region is very extensive and is the most barren large area on the island, there being only a very few small tufts of grass present. Photographs of this area taken before the eruption indicate a very sparse vegetation at that time.

The photographs of Mount Tabaro taken before the eruption (*Plate V, fig. 1*, left of picture) also indicate that it was bare or supported only scattered clumps of grass. At the present time the only vegetation on it consists of very scattered and dwarfed tufts of *Saccharum*. In the left of *plate XIV, fig. 2* is a view of this mountain. The drainage from the southwestern rim of the crater and Mount Tabaro supported some trees and scattered grass before the eruption (*Plate V fig. 1*). Now only a few clumps of *Saccharum* are present in this area (*Plate XIV, fig. 2*), but the slow revegetation is not surprising in view of the scarcity of plants before the eruption.

The growth of *Saccharum* on the upper slopes of the crater and near the rim consists very largely of scattered dwarfed tufts. The only trees observed here were a few individuals of *Ficus indica* and one of *Acacia farnesiana*. Two ferns, *Nephrolepis biserrata* and *Ceropteris calomelanos*, occur as widely scattered and dwarfed individuals on the outer slopes of the crater near the rim. *Plate XV, fig. 1*, shows the entire rim of the crater from the southeast.

In a limited area on the northwestern wall, a few meters above the floor, there is a sparse development of vegetation consisting of *Erigeron linifolius, Lygodium japonicum, Nephrolepis biserrata, Ceropteris calomelanos, Odontosoria retusa, Onychium siliquosum, Blumea lacera, Fimbristylis squarrosa*, and a single plant of *Neonauclea bartlingii*. Most parts of the inner walls of the crater are too steep to support vegetation, but here and there scattered tufts of *Saccharum* occur. Several trees, probably all of which are *Ficus indica*, occur on the northern wall of the crater. The one shown by Gates[23] is now between 5 and 6 meters high. One individual of the fern *Nephrolepis biserrata* was observed on the inner wall of the crater near the rim. On the floor of the crater there is almost nothing except scattered clumps of *Saccharum*. In a small area in the northwestern part there are, besides the *Saccharum*, scattered tufts of *Mariscus stuppeus* and *Fimbristylis squarrosa*. *Plate XV, fig. 2*, shows the walls

[23] Gates, F. C., *Philip. Journ. Sci.* 9 (1914) *Bot. pl. 10, fig. 3.*

and the floor of the crater, as viewed from about the southernmost point of the rim.

The preceding discussion shows very clearly that the revegetation of Volcano Island is proceeding in a very different manner and much more slowly than does the revegetation of land from which forest has been removed by logging. We have seen that the first invaders of the latter areas are tree species, and in two or three years the land is covered by a forest composed of small trees. The specific composition of the latter forest is very different from that of the original.

As has been shown, it would seem that both the slow revegetation of Volcano Island and the scarcity of trees should be attributed to adverse environmental conditions rather than a lack of seed.

COMPARISON WITH KRAKATAU

The early stages in the revegetation of Volcano Island have been very different from those on Krakatau. Treub,[24] who visited Krakatau three years after the destruction of the vegetation of that island, found that the new vegetation could be divided into two classes; namely, a strand vegetation, which owed its existence to seeds carried by ocean currents, and an inland vegetation, consisting very largely of 11 species of ferns. According to the observation of Treub, habitats suitable for the growth of fern prothallia were provided by blue-green algae which were very prominent in the early stages of revegetation.

Besides the ferns there were in the interior eight species of phanerograms, two of which also occurred on the strand. The remaining six species, and the previously mentioned ferns were apparently carried to the island by wind. No blue-green algae have been reported from Volcano Island, and perhaps on this account ferns have not been prominent. There are 21 species of *Pteridophyta* on the island, but these are mostly confined to deep ravines and to the sides of cliffs along the shore. They appear to be restricted largely to a substratum, which existed previous to the eruption of 1911; whereas on Krakatau the ferns were growing in new soil.

There are now 292 species of ferns and seed plants growing on Volcano Island. We call attention elsewhere to the fact that only a few of these have found a favorable habitat of any considerable extent as only 13 species are common and widely

[24] Treub, M., Notice sur la nouvelle Flore de Krakatau, *Ann. Jard. Bot. Buitenzorg* 7 (1888) 213.

distributed. In view of the fact that such a small proportion of the species that have invaded Volcano Island have become common and wide spread, it is not surprising that no phanerogams became prominent on Krakatau during the first three years after the eruption, when we consider the fact that Krakatau is much farther from the mainland than Volcano Island and so was invaded by a much smaller number of species.

In 1887, or fourteen years after the eruption of Krakatau, the island was visited by Penzig,[25] who found that the vegetation of the inland consisted of a kind of grass-steppe in which the grasses sometimes reached the height of a man and in several places formed a thick jungle. Trees were very scarce. Small grasses, ferns, and a few seed plants grow on the hills and ridges. The vegetation of the rock surfaces consisted largely of ferns and showed little change from the conditions observed by Treub in 1886.

The prominence of grasses and scarcity of trees is similar to the condition observed on Volcano Island. Grasses were much slower in becoming prominent on Krakatau than on Volcano Island; but it may be that they would have been much more prominent on Krakatau in the early stages, if their seeds had been transported to that island.

The essential differences between the revegetation of Volcano Island and Krakatau seem to be connected with the fact that Krakatau is situated in salt water and, therefore, has developed a strand formation which is lacking on Taal; while Taal being much nearer a large land mass has been invaded by many more species than Krakatau. These points will be considered later.

ENVIRONMENTAL CONDITIONS

The slowness of the revegetation of Volcano Island is probably not due, to any great extent, to the aërial environment, as the surrounding country supports a luxuriant vegetation and the indications are that it was originally covered by a tall dipterocarp forest. The unfavorable factors are apparently connected with the condition of the substratum. The most evident of these are erosion and lack of weathering of the soil particles. Most of the steeper slopes are composed of soft loose material which is very readily eroded. An extreme case of erosion is seen in *Plate XVI, fig. 2,* which shows the outer slopes of the

[25] Penzig, O., Die Forstschritte der Flora des Krakatau, *Ann. Jard. Bot. Buitenzorg* II 3 (1902) 92–113.

southwestern rim of the main crater. It will be seen that there is a considerable tendency to form deep, narrow cañons with perpendicular walls. *Plate XVI, fig. 1,* represents such a cañon on the southern side of Volcano Island. The depth of this cañon can be calculated from the size of the men in the picture. Such cañons occur on all sides of the volcano. On the upper slopes where these cañons originate, the surface consists of small rounded mounds separated by shallow depressions; the latter unite, resulting in the formation of ravines which enlarge rapidly. As these cañons reach the lower and more gradual slopes they widen and coalesce to form the large deltal fans previously discussed. The method of erosion, just described, has a very great retarding effect on the vegetation.

The volcanic materials of which the upper layers of the soil of Volcano Island are composed have apparently not been weathered into a good soil. The surface is so loose that when one walks across it the feet sink in it to a depth of several millimeters. Equally striking is the comoposition of the soil, which in many places is composed largely of fine pebbly material. In Table II are given the percentages of soil particles in the different

TABLE II.—*Analysis of soils from Volcano Island.*

[Numbers give percentages based on total dry weights.]

Source of sample.	Depth of sample.	Total humus.	Total nitrogen.	Particles not passing 1-mm sieve.	Sulphuric anhydride (SO_3).			Acidity in terms of $CaCO_3$.
					Total.	Soluble in cold water.[a]		
						After standing 12 hours.	After shaking 3 hours.	
	cm.							
Crater rim	0–10	0.35	0.02	46.50	13.29	3.10	7.20	.....
Grass area	0–10	0.98	0.05	28.58	5.00	1.28	1.96	.....
Tree-covered area	0–10	1.38	0.13	38.40	1.97	0.15	0.61	.....
Crater slopes	5–25	0.37	0.01	45.00	12.56	1.82	5.22	0.155
Grass area	7–25	0.38	0.02	3.76	4.42	0.09	0.80	0.022

[a] Soil particles not crushed; determinations were made on particles passing through a 1-mm sieve.

samples that did not pass through a 1-millimeter sieve. The surface soil at the crater rim showed 46.5 per cent of such material. Preliminary examinations indicate that the water-holding capacity of the soil is low.

The chemical properties of the soil have probably also had

an important effect on the revegetation. Cox [26] gives an analysis of ash thrown out by the eruption of 1911. This analysis shows nearly 5 per cent of material readily soluble in water, including 0.3 per cent sulphuric anhydride (SO_3) and 0.74 per cent chlorine. This would indicate that such ash would not form soil favorable for plants until after the water-soluble material had been leached out to a very considerable extent.

Shortly after the eruption the surface of the crater lake was very much lower than at present and had streams of water flowing into it. Cox gives an analysis of the water of one of these

TABLE III.—*Analyses of water of Taal Crater, Lake Bombon, and spring at Ambulong.*

[Numbers give parts per million.]

Source.	Spring at Ambulong at northeast corner of Lake Bombon (1917). [a]	Lake Bombon (1917).		Crater Lake (1917). [b]	Hot stream flowing into Crater Lake in (1911). [c]
		Near Ambulong. [a]	Near Volcano Island. [b]		
Total solids by evaporation	370.0	1,220.0	1,540.0	40,000.0	
Specific gravity at 15° C				1.02	
Acidity	4.6			0.0147 *N*	0.0069 *N*
Silica (SiO_2)	72.0	18.0	10.0	410.0	710.8
Iron and aluminum oxides $Fe_2O_3+Al_2O_3$	2.0	2.8	2.0	360.0	
Iron (Fe), total	1.4	0.24	0.14	135.0	172.0
Manganese				310.0	79.9
Aluminum (Al)	trace	1.3	.95	86.0	26.1
Calcium (Ca)	41.0	59.0	64.0	860.0	556.8
Magnesium (Mg)	120.0	400.0	50.0	2,650.0	909.3
Sodium (Na)				9,870.0	2,584.3
Potassium (K)				870.0	237.4
Chlorides (Cl)	6.1	410.0	580.0	18,300.00	6,024.3
Bromides (Br)				trace	
Iodides (I)				0.49	
Sulphates (SO_4)	23.0	160.0	194.0	3,300.0	2,732.0
Phosphates (PO_4)				18.0	
Normal carbonates (as CO_3)	0.0	12.3	24.0		
Bicarbonates	300.0	190.0	150.0		

[a] Analyzed by J. Gonzales-Nuñez, Bureau of Science, Manila.
[b] Heise, G. W., The crater lake of Taal Volcano, Philip. Journ. Sci. A 12 (1917).
[c] Cox, A. J., Philip. Journ. Sci. A 6 (1911) 96.

streams. This analysis is copied in Table III. The water contained 1.4 per cent of dissolved material, including over 0.6 per cent of chlorine, 0.26 per cent of sodium, and 0.27 per cent of the sulphate radicle (SO_4). The soil from which this high-

[26] Cox, A. J., The composition of the fine ejecta and a few other inorganic factors of Taal Volcano, *Philip. Journ. Sci. A* 6 (1911) 93–97.

mineral content was derived would certainly not be favorable for plant growth.

In order to determine something of the chemical character of the soil at the present time, we collected samples from the surface soil to a depth of 10 centimeters at the crater rim, in the grass area at the north end of the island, and in a tree-covered area on the northern slope of Mount Pirapiraso. A partial analysis of these soils was made for us by Mr. A. S. Argüelles, of the Bureau of Science. The results are given in Table II. None of the soils contained appreciable amounts of chlorine. Those from the crater rim and the grass area showed very excessive quantities of soluble sulphates. The humus and nitrogen content of the soil at the crater rim is extremely low; that of the grass area is much too low for a good soil; while even that of the tree-covered area is considerably lower than the average for Philippine soils.

The above-mentioned soil samples from the grass and the tree-covered areas contained plant roots. In the same grass area another sample of soil was taken under the roots at a depth of from 7 to 25 centimeters. The humus and nitrogen content was considerably lower than that for the surface layers, while the soluble sulphate content was very much lower. Another sample, taken on the upper slopes of the crater at a depth of from 5 to 25 centimeters, showed about the same percentage of humus as the surface sample, while the nitrogen content was even less.

Determinations of soil acidity (Table II) were made on samples of soil from the crater slopes and from the grass-covered area at the northern end of the island. In each case the acidity is very high, while that of the soil on the slopes of the crater is so extreme (0.155 per cent) that we would expect it to be very harmful to the vast majority of plants.

The chemical analysis just discussed certainly indicates that the soil of most of Volcano Island would form a very poor substratum for the growth of plants.

There is considerable evidence to show that water-soluble materials have been taken from the soil of Volcano Island at a fairly rapid rate. The land near the northwestern part of Bombon Lake near Ambulong is composed of nearly horizontal beds of water-laid volcanic tuff [27] through which there is a great seepage of water. An analysis of a sample of water taken from a large spring in the volcanic tuff at Ambulong (Table III)

[27] Pratt, W. E., Philippine lakes, *Philip. Journ. Sci. A* 11 (1916) 223–237, *pl. I.*

shows that this water does not contain an unusual amount of dissolved material; it has a total solid content obtained by evaporation amounting to 370 parts per million. The water of the lake contains a very much higher percentage of dissolved material as will be seen from the analysis in Table III. Near Ambulong the total solids amount to 1,220 parts per million and near Volcano Island to 1,540 parts per million. The large amount of dissolved material in Lake Bombon is probably derived from volcanic ejecta, and a considerable proportion of it may have come from Volcano Island.

The analysis (Table III) by Cox,[28] of water flowing into the crater lake in 1911 shows an unusual high content of dissolved mineral matter. A comparison of this analysis with the water in the crater lake in 1917 shows that the lake contains a much higher percentage of dissolved material than the water of the stream flowing into it in 1911. The amount of chlorides is about three times as great, while sodium shows an even greater increase in concentration. Calcium sulphate forms layers of considerable extent over the soil at the edge of the lake.

The amount of solid material in the water of the lake is very high, there being 40,000 parts per million. This high solid content shows that a great deal of soluble material has been taken out of the soil of Volcano Island, as the crater lake is of considerable size and depth. Pratt[29] says of this lake that after the eruption of 1911, the crater was occupied by a single lake about 1 kilometer in diameter, the surface of which was 70 meters below sea level when the first descent was made to it. Later it rose until, at the time at which he wrote, it stood at about sea level.

Another factor that will probably have considerable influence on the development of the vegetation is grass fires. In October, 1916, and January, 1917, there was no evidence of any considerable burnt areas on Volcano Island. By the first of April, 1917, fires had swept over a large portion of the north end of the island, including considerably more than half of Mount Binintiang Malaqui, much of Mount Tibag, the northern and eastern slopes of Mount Mataas-na-golod, and the northern slopes of Mount Ragatan. All these fires had occurred during the early part of the dry season; so that it may very well be that before the end of the season nearly all of the areas, in which the grass is thick enough for fire to spread from clump to clump, will have

[28] Cox, A. J., *Philip. Journ. Sci. A* 6 (1911) 96.
[29] Pratt, W. E., loc. cit.

been burned. The fires had apparently not killed any of the clumps of *Saccharum spontaneum* as, except in the most recently burnt areas, the clumps were producing new leaves. However, many trees, particularly the smaller ones, had been killed. Owing to this fact, it seems not improbable that trees may have been somewhat more numerous before fires of any considerable extent occurred on the island, than at the present time. Such trees could hardly have formed closed stands, as such stands kill the grass and fires do not burn through them. If fires continue to be prevalent on the island, it is probable that the grass areas at the northern end of the island will persist instead of being invaded by trees.

Soils derived from volcanic activity are usually very fertile, but the value of recent volcanic ejecta as a substratum for plants varies greatly. In some cases volcanic ash appears to produce a rich soil almost immediately. A conspicuous example of this is found in the region around the settlement of Kodiak, Alaska, which was covered nearly a foot deep with ash by the eruption of Mount Katmai in June, 1912.[30] The effect of the ash as described by Griggs is as follows:

> The most important settlement in the devastated district is Kodiak, which, although a hundred miles from the volcano, was buried nearly a foot deep in ash. This ashy blanket transformed the "Green Kodiak" of other days into a gray desert of sand, whose redemption and revegetation seemed utterly hopeless. When I first visited it, a year later, it presented an appearance barren and desolate. It seemed to every one there that it must be many years before it could recover its original condition.
>
> What, then, was my surprise on returning after an interval of only two years to find the ash-laden hillsides covered with verdure. Despite the reports I had received, I could not believe my eyes. Where before had been barren ash was now rich grass as high as one's head.
>
> Every one agrees that the eruption was "the best thing that ever happened to Kodiak." In the words of our hotel keeper, "Never was any such grass known before, so high or so early. No one ever believed the country could grow so many berries, nor so large, before the ash."

The above description certainly indicates that the ash thrown out by the eruption of Mount Katmai produced a very different substratum from that formed by the eruption of Taal Volcano.

The effect, on the growth of plants, of the ash thrown out by the eruption of the Soufrière in St. Vincent in 1902 was very different from the case just described and more like that of Taal.

[30] Griggs, R. F., The valley of ten thousand smokes, *National Geographic Magazine* 31 (1917) 13.

This eruption [31] devastated an extensive area of fertile, cultivated land. The depths of the covering of ejecta varied greatly in different places; [32] in some of the valleys it was from 50 to 80 feet thick; on fairly level land from 1 to 5 feet; and on steep slopes only a few inches deep. Experiments conducted in 1903 [33] with the ash showed that this was incapable of supporting plants but that if soil was mixed with the ash, fair crops of estate produce could be successfully grown.

The course of revegetation varied in different localities. In 1907 Anderson [34] found that the surface of ash near the Richmond works was not consolidated but was rapidly breaking up under the influence of plant roots, and humus was being formed. At the foot of the seaward slope of Richmond ridge there was a fan or plateau which was originally covered several feet thick with an incandescent avalanche. The surface of this consolidated into a crust nearly an inch thick. In 1907 Anderson found that no plants sprang up where this crust was perfect, but that where it was broken, as along the small water courses, a few plants were found.

The progress of revegetation in the above areas was described by Sands [35] in 1912 as follows:

> Starting from the ruined Richmond plantation works, it is seen that the ejecta, mixed to some extent with old soil brought down by rains from the higher lands above, are from 2 to 6 feet thick, and are being rapidly converted into soil under the influence of favorable climate conditions, the action of the roots of various plants and decaying organic matter * * *. With the exception of the Roseau grass [*Gynerium saccharoides* HBK.], the roots of which had not been killed, all the plants have gradually established themselves from seed brought by various agencies from lands near by * * *.
>
> From Richmond works, proceeding along the coast in the direction of the volcano, a plateau of ash is soon reached which was put down in the form of an incandescent avalanche. This avalanche destroyed Richmond village, and covered the northwest portion of the plantation lands to a depth of

[31] Anderson, T. and Flett, J. S., Report on the Eruption of the Soufrière in St. Vincent in 1902, and on a Visit to Montagne Pelée, in Martinique.—Part I, *Phil. Trans. Roy. Soc. London* Sec. A. 200 (1903) 353–553.

[32] Sands, W. N., An account of the return of vegetation and the revival of agriculture, in the area devastated by the Soufrière of St. Vincent in 1902–3, *West Indian Bull.* 12 (1912) 22–31.

[33] Sands, W. N., loc. cit.

[34] Anderson, T., Report on the Eruption of the Soufrière, in St. Vincent, in 1902, and on a Visit to Montagne Pelée, in Martinique.—Part II, *Phil. Trans. Roy. Soc. London* Sec. A. 200 (1908) 275–303.

[35] Sands, W. N., *West Indian Bull.* 12 (1912) 22–31.

several feet. It is observed that the top layer of ash has formed a crust, but this has been broken up at frequent intervals by heavy rains; the result is that numerous shallow water-channels have been formed. It is observed that it is only in these depressions that plants have been able to get a root-hold. The chief plant lining the sides is the silver fern (*Gymnogramme calomelanos*, Kaulf.) [=*Ceropteris calomelanos* Und.], which is playing the important part of preparing the ash for higher types. Already a few hardy plants such as the hurricane grass (*Arundinella martinicensis*, Trin.), *Emilia sonchifolia*, DC., cattle-tongue (*Pluchea odorata*, Cass.), *Eupatorium odoratum*, L., and a sedge or two are found growing with the ferns. Here it is evident that these are the true ash plants, and have grown from spores and fruits brought by wind and water; but chiefly by the former.

Areas, in which the destruction of the vegetation was not complete or where the ash has subsequently been largely washed away, have become covered with plants.

On the upper slopes of the volcano revegetation has been slow as will be seen from the following statement by Sands:

At 1,400 feet, plants are scantily distributed and the growth is poor. Only the hardy bamboo and Roseau grasses, silver ferns and tree-ferns, *Freziera hirsuta*, Sw., and *Eupatorium odoratum*, L., appear to thrive. Here, however, is found the pretty moss *Lycopodium cernuum*, L., and the somewhat rare *Eupatorium ossaeanum*, DC. At 2,000 feet, silver ferns and mosses only are seen. From this altitude to the lower lip of the crater, which aneroid barometer readings indicate to be 2,800 feet above sea level, the ejecta assume a coarse, cindery form, in which at present only algae, mosses, and lichens are able to exist.

According to Anderson,[36] the early stages of the revegetation of Mount Pelèe were similar to those of the Soufrière.

In view of the fact that both the chemical and the mechanical compositions of volcanic ejecta vary greatly, it is not surprising that the effect on plants should be different in different cases. Probably the most usual condition is for recent ejecta to form a poor substratum for plants. This is particularly true of lava flows, which have to be weathered very considerably before they can support higher plants. Very interesting examples of this phenominon have been described from the Hawaiian Islands by Rock.[37]

Even when the ejecta form a soil composed of fairly small particles, such a soil is very frequently a poor substratum for plants until a considerable period has elapsed, when the soil has apparently been weathered and leached.

[36] Anderson, T., *Phil. Trans. Roy. Soc. London* Sec. A. 200 (1908) 275–303.

[37] Rock, J. F., The indigenous trees of the Hawaiian Islands. Honolulu (1913).

It is a common observation that the upper slopes of active volcanoes are usually very bare, and this is frequently the case even when there have been no recent eruptions.

Schimper [38] visited the volcano of Gunong Guntur in western Java many years after the vegetation had been completely destroyed by an eruption and found the vegetation quite open and very poor.

> There are absolutely no trees, but shrubby and herbaceous plants of very various species were present. * * *. The most essential part was played by plants that grew as epiphytes in the neighboring woods, namely many orchids, as well as several ferns and the shrubby *Rhododendron javanicum*, * * *.

The picture that Schimper gives of this vegetation indicates that the ground was very largely bare and that, as on the larger part of Volcano Island, the plants were very scattered.

Another interesting example of a sparse vegetation on a volcanic cone is afforded by the Gedeh in western Java. The active crater is a small cone within a much larger ancient crater. The slopes of the mountain and most of the ancient crater are covered by a dense and varied vegetation, while the slopes of the new cone, although signs of volcanic activity are very slight, show a very sparse vegetation. This mountain was visited by Brown and Yates in 1917. On the active cone there were present only the following 9 species of higher plants and ferns:

Gaultheria nummularioides G. Don.
Gaultheria leucocarpa Bl.
Gaultheria fragrantissima Wall.
Rhododendron retusum Benn.
Vaccinium varingiifolium (Bl.) Miq.
Anaphalis javanica Sch.
Carex hypsophila Miq.
Histiopteris incisa J. Sm.
Polypodium feeii Bory.

These include 5 *Ericaceae*, 1 composite, 1 sedge, and 2 xerophytic ferns. These plants were very scattered and all were small, there being no specimen on the active cone that was more than 0.5 meter in height. The density of the vegetation was very similar to that shown in Schimper's photograph taken on Gunong Guntur.

It seems evident that the invasion of soils of recent volcanic origin varies very greatly in different cases, and our present knowledge does not appear to justify us in trying to establish any general laws.

[38] Schimper, A. F. W., Plant-Geography upon a Physiological Basis. Eng. trans. by W. R. Fisher. Clarendon Press, Oxford (1903).

DISTRIBUTION OF SPECIES

For convenience of reference we have brought together in Table IV data on the relative abundance, the method of distribution, and the geographic origin and distribution of all the species that have been found on Volcano Island since the eruption in 1911.

The relative abundance of the individual species is merely approximate, as no exact counts were taken. Under "very rare" are listed those species observed only in one or two localities, and represented by a single or very few specimens; "rare or local" indicates those species which, while more abundant than the above, are not conspicuous and are usually confined to a limited area; "fairly common" includes those of general distribution that are not dominant; by "very common" are indicated the comparatively few species that are widely distributed and dominant.

In listing the methods of distribution of seeds we have considered only those means by which they are carried to a considerable distance and have left out of account those devices, such as explosive pods which can distribute the seeds only a few meters. Very few actual experiments have been performed to determine the possible methods of distribution so that we have relied on inferences drawn from the character of the fruits, supplemented, in many cases, by direct observation. While the data cannot threfore be regarded as exact, they should be sufficiently accurate to allow general conclusions to be drawn from them.

Under the heading "eaten by birds" are placed most of the species with fleshy fruits as well as some species with dry fruits that are known to be distributed by birds.

The heading "wind" includes those seeds with definite wings, pappus, or other appendages adapted to aërial dispersal; also the minute, dust-like seeds of the *Orchidaceae* and the spores of ferns.

Under "water" are placed those species that have manifest adaptations for dispersal by means of floating seeds or fruits. Some species whose fruits are not specially suited for this method of dissemination have reached Volcano Island by floating as the distance from the shore of the mainland to the island is not great. Viable seeds of *Samanea saman*, *Cucurbita maxima*, and *Citrullus vulgaris* were found in the drift on the beach. Even more conspicuous was a large fleshy fruit of *Artocarpus integrifolia* with the fruit as well as the seeds in perfect condition. None of

the above plants appear to be specially adapted for dispersal by floating. Owing to the short distance from the mainland it is probable that many other seeds having no special adaptation for floating have reached the island by this means. Some, which by themselves cannot float at all, may have been carried by floating drift. This is particularly true, since in a short time the fresh water would not impair the germinating power of the seeds. It is a well-known fact that most of the seeds of tropical weeds will not float and this is apparently true of most species with minute seeds. This fact, however, does not preclude the possibility that some of these plants may have been transported by the last-mentioned method.

The heading "organs for adhering" includes those seeds and fruits with hooks and spines, barbed or viscid hairs, or other special adaptation by which they adhere to the fur of animals, the clothing of man, or the feathers of birds. *Hyptis suaveolens*, a most successful weed, falls in this group on account of the gelatinous viscid covering of the wet seeds.

Under the heading "eaten by animals" are placed those plants eaten by cattle and which may be disseminated by such seeds as are not digested. Most of these seeds are minute and very hard. It is probable that some species have thus reached Volcano Island, and it is certain that a number of them have been disseminated over the island by this means as a considerable number of cattle, carabaos, and horses range on the island.

Under the heading "man" are included those species that are usually disseminated only or chiefly by man. *Annona reticulata*, custard apple; *Arachis hypogaea*, peanut; *Bambusa* spp., cultivated bamboos; *Ipomoea batatas*, sweet potato; *Oryza sativa*, rice; *Manihot utilissima*, cassava; *Musa* sp., banana; and a few others are found on the island.

Under "minute seeds" we have placed a large number of species—characteristic fresh-water plants, rice-paddy weeds, and others—which are for the most part of very wide geographic distribution; but whose seeds usually do not float, are not adapted for dissemination by the wind, and yet are most successful emigrants. Many, if not most, of these are distributed through the medium of mud, in which the seeds are imbedded in large numbers, adhering to the feet and coats of birds and other animals.

There are a number of species—some of them are very wide distribution and abundant in all tropical countries—that we have not succeeded in classifying according to the method by which

their seeds are distributed, as we have not observed any evident means of dissemination.

Under geographic origin and distribution we have indicated species of American origin; species of Asiatic origin; the endemic species; those distributed in all or some parts of the Indo-Malayan region in addition to the Philippines; and those of pantropic distribution, including the species naturally occuring in both hemispheres and the ones that have been purposely or accidentally transmitted by man from one hemisphere to the other. In some cases it has been impossible to determine the origin of species of pantropic distribution.

In the enumeration in Table IV of the plants found on Volcano Island, we have included only the vascular crytogams and the phanerogams. The cellular cryptogams are for the most part conspicuous by their absence. Along the coast a few of the rocks subject to the wash of the waves are densely covered by a species of *Cladophora*, but on the bare soil of the island there is no indication of an algal growth such as Treub [39] found on Krakatau, from which he assumed that the *Cyanophyceae*, diatoms, and other algae prepared the soil for the reception of seeds and spores of higher plants. The only lichen observed was a single species, apparently *Bilimbia artytoides* (Nyl.), on the walls of a few cañons, this being locally abundant; no lichens were observed on the bark or the leaves of trees, although a careful search was made for such forms. The *Hepaticae* are represented by *Anthoceros spongiosus* Steph. and an undetermined form; the *Musci* by *Trematodon acutus* C. Müll. and two or three other, undetermined species. The mosses and hepatics, however, are confined to the damp ravines and the damp soil of bluffs near the shore, and are abundant only in very limited areas.

A considerable number of the species mentioned in Table IV were represented by a single plant, and nearly every one of the deeper ravines in the northern part of the island contained at least one species not observed elsewhere. It is, therefore, unreasonable to suppose that every species growing on the island has been detected; but it is practically certain that the list does include all species that are either abundant or prominent, and the number of species not included is probably small.

In Table IV the species found by Gates, but not observed by us in 1916–17, thirteen in number, are indicated by a dagger while those observed in 1916–17, but not found by Gates, are

[39] Treub, M., Ann. Jard. Bot. Buitenzorg 7 (1887) 213.

indicated by an asterisk. The species observed by Gates, but not found by us are:

Antidesma rostratum.
Aerua lanata.
Citrullus vulgaris.
Ficus nervosa.
Gymnema tingens.
Ipomoea batatas.
Crataeva religiosa.
Cyperus radiatus.
Elaeagnus philippensis.
Lemna trisulca.
Muntingia calabura.
Oryza sativa.
Phaleria cumingii.

Of these species *Oryza sativa, Citrullus vulgaris,* and *Ipomoea batatas* are cultivated forms dependent on man for their persistence, and they may no longer occur on Volcano Island, as the plants observed by Gates were probably merely adventive ones. *Lemna trisulca* was represented only by plants thrown up on the shore; while *Cyperus radiatus,* a marsh plant, which was local along the shore, probably occurred in a very unstable habitat. The remaining eight species, mostly conspicuous ones, must now be rare or at least very local on the island, otherwise they would in all probability have been detected in 1916–17.

It has been necessary to make a few alterations in Gates's list, on account of changes in nomenclature. In some cases he was not able to collect material suitable for identification, and a comparison of his specimens with the collections of 1916–17 has necessitated a few corrections. *Atalantia disticha* and *Sida cordifolia,* enumerated by Gates, are not included in Table IV, as the only specimens of these plants collected by him were from a neighboring island. Gates's list, with the changes indicated above, includes 175 species.

In Table IV are listed 117 additional species, nearly all of which must have invaded the island between April, 1914, and January, 1917. It is, of course, probable that Gates overlooked a few species growing on the island at the time of his visit, and this is apparently true of *Bambusa vulgaris, Arytera littoralis,* and *Erioglossum rubiginosum.* The last two are arborescent species and are now represented by mature specimens. However, the number of species that Gates overlooked must be very small.

The total number of species in Table IV is 292. Among these are included nearly two-thirds of the 236 species listed by Centeno as having been collected on the island between 1877 and 1879. Centeno's list was evidently very incomplete, and it is probable that it contains in general the plants that were the most common and conspicuous on the island. The high percentage of species in this list which have been collected on the

island since the eruption in 1911 indicates that about two-thirds of the species which were common before the eruption occur on the island at the present time.

The invasion of Volcano Island by new species has evidently taken place at a very rapid rate. However, only thirteen species are listed in Table IV as common and widely distributed. This indicates that few of the species have found favorable habitats of considerable extent and affords additional evidence that the slowness of revegetation is due to adverse environmental conditions rather than to a lack of seeding.

A large proportion of the species are widely distributed in the tropics. Ninety-six, or 33 per cent, are of pantropic distribution; while an additional one hundred fifty, or 51 per cent, are found in other parts of the Indo-Malayan region as well as in the Philippines. Only forty-six, or 16 per cent, are confined to the Philippine archipelago. Most of the species on Volcano Island are common and widely distributed in inhabited areas at low altitudes in the Philippines. Merrill [40] has shown that in such regions the percentage of endemic species is small, being only about 12 per cent. In his calculations cultivated as well as spontaneous species are considered. The percentage of endemism among spontaneous species would be somewhat greater.

The preponderance of widely distributed plants in the cultivated areas in the Philippines is similar to the condition prevailing in many tropical countries. The wide distribution of these species is due to the fact that many tropical countries originally supported tall dense forests, the removal of which, produced conditions suitable for plants more xerophytic than most of those previously occurring in the region. The artificial production of similar habitats in many parts of the tropics has made it possible for plants suitable for those habitats to become widely distributed, largely through the agency of man, either purposely or accidentally.

Most of the species on Krakatau are also of wide distribution. In speaking of those in the interior of the island Ernst [41] says:

> Within their respective distribution-areas they belong to the commonest plants and to such as grow indifferently in a great variety of habitats. These constituents of the new Krakatau flora owe their occurence in the new habitat, as also their wide distribution, chiefly to the efficient adaptation of their fruits and seeds to distant transport.

[40] Merrill, E. D., Notes on the Flora of Manila with special reference to the introduced element, *Philip. Journ. Sci.* 7 (1912) *Bot.* 145–208.

[41] Ernst, A., The New Flora of the Volcanic Island of Krakatau (1908) 48.

This statement is certainly applicable to most of the plants on Volcano Island. The percentage of species common to the two islands is, however, small. Ernst gives a list of forty-one species occurring in the interior and not on the strand. Only eleven of these are found on Volcano Island, although twenty-four occur in the Philippines. The plants found on Krakatau indicate a climate distinctly more moist than that of Taal.

The species occurring on the strand of Krakatau would naturally be different from those on Volcano Island. Ernst mentions sixty-seven species on the strand of Krakatau. Of these eleven are found on Volcano Island, while fifty-five are known from the Philippines.

From the data given in Table IV we have calculated the approximate percentage of plants distributed by different means. For reasons which have already been explained, the calculations cannot be made exact.

Birds would appear to be the most important agency of dispersal. Eighty-three, or 28 per cent, are listed as being eaten by birds; fourteen, or 5 per cent, have organs for adhering and so may be carried by birds; while sixty, or 21 per cent, are characterized by minute seeds which could be distributed in mud on the feet or the feathers of birds. There are thus one hundred fifty-seven species, or 54 per cent, of the total on the island which could have been carried to it by birds.

Sixty, or 21 per cent, are apparently distributed by wind; while only twenty-six, or 9 per cent, are adapted to dispersal by water.

Thirty-nine, or 13 per cent, can be scattered by being eaten by animals. As a considerable number of cattle and carabao have been taken to the island since the eruption, a number of the above plants may have reached the island or have been subsequently distributed over it by this means. Many of the plants in this category are also included among those that could be disseminated by birds or wind.

Twenty-one species, or 7 per cent, are normally distributed by man. At least three of these, *Bambusa blumeana*, *B. vulgaris*, and *Musa sapientum*, are relics of former cultivation on the island. A few of the species may have been distributed by man since the eruption. Some of the species that are usually distributed by man are also distributed by birds and in our calculations are included under both headings. A few species, usually distributed by man, which are not particularly adapted for floating have evidently reached the island by the latter means.

Owing to the short distance between Volcano Island and the

mainland a number of different methods have been effective in carrying seeds to the island. More species seem to have been introduced by birds than by any other single agency. Birds have also been effective in scattering seeds on the island as, with a single exception, all of the commonest tree species are distributed by them. Next to birds, wind has brought the largest number of species to the island. When the predominance of grasses is considered it would seem that this agency is responsible for the presence of the bulk of vegetation on the island.

The relative effectiveness of the various methods of dispersal has been quite different in the case of Krakatau.[42] Owing to the greater distance of Krakatau from the mainland the invasion by different species has been slower than on Volcano Island. Twenty-three years after the destruction of the vegetation of Krakatau this island was visited by Ernst who gives a list of the species that had been collected on it up to that time. This list includes ninety-two seed plants and sixteen *Pteridophyta*. Ocean currents had been the most important method by which phanerograms had reached the island. According to Ernst 39 per cent had certainly been carried to the island by this means, while the number that might have been introduced by sea currents amounted to 72 per cent of the total. The number of seed plants that almost certainly had been transported by wind amounted to 16 per cent, while the addition of those that might possibly have been carried by this method would bring the total to 32 per cent. Birds were apparently much less effective than the two agencies just mentioned. Ernst says that 10 per cent of the total were certainly introduced by this method while an additional 9 per cent may, possibly, have been so transmitted.

A comparison of the invasion of Krakatau and Volcano Island shows a very apparent difference in the efficiency of dispersal by birds over long and short distances. Not only is the number of species distributed by this means much greater in the case of Volcano Island, but the percentage is also greater. This is in harmony with the observation of Kerner[43] that the interval between eating and ejecting of food is in the case of most birds, from one and a half to three hours. Wind has carried many more species to Volcano Island than to Krakatau. This is, of course, due to the greater distance in the latter case. The percentage of species introduced on Krakatau during the first four-

[42] Ernst, A., op. cit.

[43] Kerner, A., The Natural History of Plants. Translated by F. W. Oliver, 2: 864.

teen years after the eruption and which were carried by wind was, however, greater than has been the case on Volcano Island.

The difference in the effectiveness of water in transporting seeds cannot be accurately compared in the case of Volcano Island and Krakatau as the former is situated in fresh and the latter in salt water.

TABLE IV.—*Distribution and methods of distribution of plants found on Volcano Island since the eruption of Taal Volcano in 1911.*

[The * indicates additions to Gates's 1914 list; the † indicates species of Gates's that were not observed on Volcano Island in 1916–1917.]

Species.	Relative abundance.				Method of distribution.							Geographic origin and distribution.				
												Origin.		Distribution.		
	Very rare.	Rare or local.	Fairly common.	Very common and widely distributed.	Eaten by birds.	Wind.	Water.	Organs for adhering.	Eaten by animals.	Man.	Minute seeds.	American.	Asiatic.	Endemic.	Indo-Malaya.	Pantropic.
Abrus precatorious		×			(?)								×			×
Acacia farnesiana				×					(?)			×				×
*Acrostichum aureum**		×				×										×
*Adiantum caudatum**		×				×							×		×	
Adiantum philippense		×				×										×
Aerua lanata †		×									×		×		×	
*Aganosma acuminata**		×				×							×		×	
Ageratum conyzoides			×			×						×				×
Albizzia procera			×										×		×	
Allaeanthus luzonicus	×				×								×	×		
*Alstonia macrophylla**	×					×							×		×	
Alstonia scholaris		×				×							×		×	
Alternanthera sessilis		×									×					×
Alysicarpus vaginalis			×										×			×
Amaranthus spinosus			×								×					×
Amorphophallus campanulatus	×				×								×		×	
*Andropogon fragilis**	×							×	×				×		×	
*Aneilema malabaricum**	×										×		×		×	
*Anisomeles indica**		×									×		×		×	
*Annona reticulata**	×				×					×		×				×
Antidesma bunius			×		×								×		×	
Antidesma ghaesembilla				×	×								×		×	
Antidesma rostratum †	×				×								×	×		
Arachis hypogaea	×									×		×				×
Arenga saccharifera	×								(?)	×			×		×	
*Aristolochia tagala**		×				×							×		×	
Artocarpus lamellata	×				×								×	×		
*Arytera littoralis**	×				×								×		×	
Bambusa blumeana		×								×			×		×	
*Bambusa vulgaris**	×									×			×			×
*Blechnum orientale**			×			×							×		×	

TABLE IV.—*Distribution, etc.*—Continued.

Species.	Relative abundance.				Method of distribution.							Geographic origin and distribution.				
												Origin.		Distribution.		
	Very rare.	Rare or local.	Fairly common.	Very common and widely distributed.	Eaten by birds.	Wind.	Water.	Organs for adhering.	Eaten by animals.	Man.	Minute seeds.	American.	Asiatic.	Endemic.	Indo-Malaya.	Pantropic.
Blechum brownei *		×										×				×
Blumea balsamifera			×			×							×		×	
Blumea lacera			×			×							×		×	
Blumea mollis *			×			×							×		×	
Blumea glomerata *		×				×							×		×	
Boehmeria blumei *			×								×		×		×	
Bonnaya brachiata *			×						×		×		×		×	
Breynia acuminata		×			×								×	×		
Breynia cernua		×			×								×		×	
Breynia rhamnoides		×			×								×		×	
Bridelia stipularis			×		×								×		×	
Bryonopsis laciniosa *		×			×								×		×	
Buddleia asiatica			×			×							×		×	
Bulbostylis barbata				×					×		×		×		×	
Caesalpinia crista *		×					×						×			×
Callicarpa blancoi				×	×								×	×		
Calotropis gigantea *		×				×							×		×	
Calonyction album *		×										×				×
Canavalia ensiformis			×				(?)						×		×	
Canavalia lineata		×					×									×
Cantharospermum scarabaevides			×						×				×		×	
Capparis horrida			×		×								×		×	
Capparis micracantha		×			×								×		×	
Capsicum fruticosum *		×			×							×				×
Carica papaya		×			×							×				×
Casearia cinerea			×		×								×	×		
Cassia alata *	×											×				×
Cassia tora *	×								(?)			×				×
Cassytha filiformis		×					×									×
Ceiba pentandra		×				(?)				×		×				×
Celastrus paniculata			×		×								×		×	
Centella asiatica *		×							×							×
Ceratophyllum demersum		×									×					×
Ceropteris calomelanos *			×			×						×				×
Cheilanthes tenuifolia *		×				×							×		×	
Cissampelos pareira		×			×											×
Cissus repens		×			×								×		×	
Citrullus vulgaris †	×									×			×			×
Cnestis diffusa *		×			×								×	×		
Clerodendron minahassae			×		×								×		×	
Clitoria ternatea *	×									×		×				×
Columella (Cissus) trifolia		×			×								×		×	
Commelina benghalensis *	×										×		×		×	

TABLE IV.—*Distribution, etc.*—Continued.

Species.	Relative abundance.				Method of distribution.							Geographic origin and distribution.				
												Origin.		Distribution.		
	Very rare.	Rare or local.	Fairly common.	Very common and widely distributed.	Eaten by birds.	Wind.	Water.	Organs for adhering.	Eaten by animals.	Man.	Minute seeds.	American.	Asiatic.	Endemic.	Indo-Malaya.	Pantropic.
Commelina nudiflora		×									×					×
*Corchorus acutangulus**	×										×		×		×	
Cordia myxa Linn.			×		×								×		×	
Crataeva religiosa†	×				×								×		×	
Cratoxylon blancoi		×				×							×	×		
Crotalaria albida			×						(?)				×		×	
*Crotalaria acicularis**		×							(?)				×		×	
*Crotalaria stenophylla**		×							×				×		×	
*Crotalaria verrucosa**	×						(?)						×		×	
*Cyanotis cristata**		×									×		×		×	
*Cucurbita maxima**	×								×	×		×				×
Cynodon dactylon		×							×		×					×
Cyperus compressus		×							×		×					×
Cyperus diffusus		×							×		×		×		×	
Cyperus distans		×							×		×		×		×	
Cyperus radiatus†	×								×		×		×		×	
*Cyperus rotundus**		×							×		×					×
*Cyperus uncinatus**		×							×		×		×		×	
Dactyloctenium aegyptium		×							×		×		(?)			×
Datura alba		×					(?)						×		×	
Deeringia baccata		×			×								×		×	
Derris polyantha		×											×	×		
Desmodium gangeticum			×					×					×			×
*Desmodium procumbens**	×							×				×				×
Desmodium pulchellum			×					×					×		×	
Desmodium scorpiurus			×					×				×				×
Desmodium triflorum			×					×								×
Digitaria consanguinea		×							×		×		×		×	
*Digitaria ciliaris**		×							×		×					×
Dioscorea bulbifera	×					×							×		×	
Dioscorea luzonensis		×				×							×	×		
*Dioscorea myriantha**	×					×							×		×	
*Dioscorea triphylla**	×					×							×		×	
*Dioscorea aculeata**		×				×							×		×	
Dracontomelum cumingianum	×				×								×	×		
*Dryopteris parasitica**	×					×										×
Eclipta alba		×					×						×			×
*Eclipta zippeliana**	×						×						×		×	
Elaeagnus philippensis†	×				×								×	×		
Eleusine indica		×							×		×					×
Emilia sonchifolia		×				×							×			×
*Eragrostic amabilis**		×							×		×					×

TABLE IV.—*Distribution, etc.*—Continued.

Species.	Relative abundance.				Method of distribution.						Geographic origin and distribution.				
											Origin.		Distribution.		
	Very rare.	Rare or local.	Fairly common.	Very common and widely distributed.	Eaten by birds.	Wind.	Water.	Organs for adhering.	Eaten by animals.	Man.	Minute seeds.	American.	Asiatic.	Endemic.	Indo-Malaya.	Pantropic.
*Eragrostis distans**		×							×		×		×	×		
Erigeron linifolius		×				×						×				×
*Erioglossum rubiginosum**	×				×									×	×	
Erythrina indica	×						×						×		×	
Eugenia jambolana				×	×					×			×			×
*Eulophia squalida**	×				×								×		×	
*Euphorbia hirta**		×									×					×
*Ficus concinna**	×				×								×	×		
Ficus cumingii			×		×								×	×		
Ficus hauili				×	×								×	×		
Ficus indica				×	×								×			×
Ficus nervosa†	×				×								×		×	
*Ficus nota**	×				×								×	×		
*Ficus odorata**	×				×								×	×		
*Ficus stipulosa**	×				×								×	×		
Ficus tinctoria		×			×								×		×	
Ficus ulmifolia			×		×								×	×		
*Fimbristylis merrillii**	×								×		×		×	×		
*Fimbristylis polytrichoides**			×						×		×		×		×	
*Fimbristylis squarrosa**		×							×		×					×
*Flacourtia rukam**	×				×								×		×	
Fluggea virosa			×		×								×		×	
*Gleichenia linearis**	×					×							×		×	
Gliricidia sepium			×							×		×			×	
*Glochidion rubrum**	×				×								×	×		
Glochidion triandrum		×			×								×	×		
*Gmelina philippensis**		×			×								×	×		
Gymnema pachyglossum		×				×							×	×		
Gymnema tingens†	×					×							×		×	
*Hedyotis tenelliflora**	×										×		×		×	
Heliotropium indicum		×									×		×			×
*Hemigraphis rapifera**	×												×		×	
*Hemionitis arifolia**		×				×							×		×	
*Hetaeria oblongifolia**	×					×							×		×	
*Hibiscus surattensis**	×												×		×	
Hewittia sublobata		×											×		×	
*Hygrophila angustifolia**	×						×						×		×	
*Hyptis suaveolens**	×							×				×				×
Imperata cylindrica var. *koenigii*			×			×							×		×	
Ipomoea batatas†	×									×		×				×
Ipomoea obscura		×											×		×	

TABLE IV.—*Distribution, etc.*—Continued.

Species.	Relative abundance.				Method of distribution.							Geographic origin and distribution.				
												Origin.		Distribution.		
	Very rare.	Rare or local.	Fairly common.	Very common and widely distributed.	Eaten by birds.	Wind.	Water.	Organs for adhering.	Eaten by animals.	Man.	Minute seeds.	American.	Asiatic.	Endemic.	Indo-Malaya.	Pantropic.
Ipomoea pescaprae				×			×					×				×
*Ipomoea paniculata**		×					×					×				×
Ipomoea pestigridis		×											×		×	
*Ipomoea reptans**	×						×						×		×	
Ipomoea triloba		×										×				×
*Kyllinga monocephala**	×								×		×		×		×	
Jussiaea repens	×						×				×					×
*Jussiaea linifolia**	×										×	×				×
Lemna trisulca†	×						×				×					×
Leucas javanica		×											×		×	
Lindenbergia philippensis		×									×		×		×	
Litsea glutinosa			×		×								×		×	
Luffa cylindrica			×				×			×			×			×
*Lycopodium cernuum**	×					×						×				×
Lycopersicum esculentum	×				×					×		×				×
Lygodium japonicum		×				×							×		×	
*Lygodium scandens**		×				×							×		×	
Macaranga tanarius			×		×								×		×	
Maesa cumingii			×		×								×	×		
Maesa laxa Mez*		×			×								×	×		
*Malaisia scandens**	×				×								×		×	
Mallotus moluccanus			×		×								×		×	
Manihot utilissima	×									×		×				×
Mariscus stuppeus		×					(?)				×		×		×	
*Melothria mucronata**	×				×								×		×	
Mezoneurum latisiliquum		×					(?)						×		×	
*Microlepia speluncae**		×				×							×		×	
Miscanthus sinensis		×				×							×		×	
*Mitrosacme alsinoides**			×								×		×		×	
Momordica charantia		×			×								(?)			×
Momordica cochinchinensis		×			×								×	×		
Momordica ovata			×		×								×		×	
Morinda bracteata				×	×		(?)						×		×	
Moringa oleifera	×									×			×		×	
*Mucuna nigricans**	×						×						×		×	
Muntingia calabura†	×				×							×				×
Musa sapientum		×								×			×			×
*Mussaenda philippica**	×				×								×	×		
Nephrolepis biserrata			×			×										×
*Neonauclea bartlingii**	×					×							×	×		
*Notholaena dense**	×					×							×		×	
Odontosoria chinensis			×			×							×		×	

TABLE IV.—*Distribution, etc.*—Continued.

Species.	Relative abundance.				Method of distribution.							Geographic origin and distribution.				
												Origin.		Distribution.		
	Very rare.	Rare or local.	Fairly common.	Very common and widely distributed.	Eaten by birds.	Wind.	Water.	Organs for adhering.	Eaten by animals.	Man.	Minute seeds.	American.	Asiatic.	Endemic.	Indo-Malaya.	Pantropic.
Oldenlandia corymbosa		×									×		×			×
Onychium siliquosum		×				×							×		×	
Operculina turpethum		×					(?)									×
Oplismenus compositus *		×						×	×				(?)			×
Oroxylum indicum		×				×							×		×	
Oryza sativa †	×									×			×			×
Otophora fruticosa *		×				×							×		×	
Ottelia alismoides *		×					×				×		×		×	
Pachyrrhizus erosus	×									×		×				×
Pandanus tectorius	×						×						×		×	
Panicum carinatum *		×							×		×		×	×		
Panicum caudiglume		×							×		×		×		×	
Panicum distachyum		×							×		×		×		×	
Panicum repens		×					(?)		×							×
Paspalum distichum		×					(?)		×							×
Paspalum scrobiculatum		×							×				×		×	
Pericampylus incanus		×			×								×		×	
Phaleria cumingii †	×				×								×	×		
Phaseolus adenanthus *			×				×									×
Phragmites vulgaris		×				×										×
Phyllantus erythrotrichus		×									×		×	×		
Physalis minima *		×			×							×				×
Pipturus arborescens			×		×								×		×	
Pistia stratiotes		×					×				×		×		×	
Pithecolobium dulce				×	×							×				×
Poganatherum paniculatum *	×					×							×		×	
Polanisia viscosa	×										×					×
Pongamia pinnata		×					×						×		×	
Portulaca oleracea	×										×					×
Polygonum barbatum *	×						(?)						×		×	
Pouzolzia zeylanica *	×										×		×		×	
Premna nauseosa		×			×								×	×		
Premna odorata *		×			×								×	×		
Psidium guajava			×		×							×				×
Pteris vittata		×				×							×		×	
Pteris quadriaurita		×				×							×		×	
Pterocaulon cylindrostachyum		×				×							×		×	
Pueraria phaseoloides *			×						×				×		×	
Pycreus nitens *	×								×				×		×	
Pycreus holosericeus *	×								×				×		×	
Pycreus odoratus *			×						×							×
Pyxidaria crustacea		×									×		×		×	

TABLE IV.—*Distribution, etc.*—Continued.

Species.	Relative abundance.				Method of distribution.							Geographic origin and distribution.				
												Origin.		Distribution.		
	Very rare.	Rare or local.	Fairly common.	Very common and widely distributed.	Eaten by birds.	Wind.	Water.	Organs for adhering.	Eaten by animals.	Man.	Minute seeds.	American.	Asiatic.	Endemic.	Indo-Malaya.	Pantropic.
Pyxidaria pusilla			×								×		×		×	
Quisqualis indica		×											×		×	
Ricinus communis		×					(?)			×			×			×
*Rottboellia exaltata**	×								×				×		×	
Rourea erecta		×			×								×	×		
Saccharum spontaneum				×		×							×		×	
*Samanea saman**	×						×			×		×				×
Scoparia dulcis		×									×	×				×
Selaginella belangeri		×				×							×		×	
Semecarpus cuneiformis			×		×								×	×		
Sesbania cannabina	×						×						×		×	
Sida acuta		×						×								×
Sida rhombifolia		×						×								×
*Solanum cumingii**	×				×								×	×		
*Solanum nigrum**	×				×							×				×
*Solanum verbascifolium**		×			×											×
Spermacoce hispida		×									×		×		×	
*Sphaeranthus africanus**	×					×							×		×	
*Spirodela polyrrhiza**	×						×				×					×
*Stictocardia campanulata**	×						(?)						×		×	
Streblus asper		×			×								×		×	
*Stenochlaena palustris**	×					×							×		×	
Sterculia foetida		×					(?)						×		×	
Streptocaulon baumii			×			×							×	×		
Synedrella nodiflora		×						×				×				×
Tabernaemontana pandacaqui			×		×								×	×		
Tabernaemontana subglobosa				×	×								×	×		
Tephrosia dichotoma		×							×				×	×		
*Terminalia catappa**	×						×						×			×
Tetrastigma harmandii		×			×								×		×	
*Torenia pedunculoris**	×										×		×		×	
Themeda gigantea			×			×							×		×	
*Torulinium ferax**	×						(?)				×					×
Tournefortia sarmentosa		×			×								×		×	
Trema orientalis				×	×								×		×	
*Trianthema monogyna**	×						(?)				×		×		×	
*Trichodesma zeylanicum**	×										×		×		×	
Triumfetta bartramia			×					×								×
*Tylophora perrottetiana**	×					×							×	×		
*Urena lobata**		×						×								×
Vallisneria gigantea		×					×				×		×		×	

TABLE IV.—*Distribution, etc.*—Continued.

Species.	Relative abundance.				Method of distribution.							Geographic origin and distribution.				
												Origin.		Distribution.		
	Very rare.	Rare or local.	Fairly common.	Very common and widely distributed.	Eaten by birds.	Wind.	Water.	Organs for adhering.	Eaten by animals.	Man.	Minute seeds.	American.	Asiatic.	Endemic.	Indo-Malaya.	Pantropic.
Vernonia patula *	×					×							×		×	
Vernonia cinerea			×			×							×		×	
Vigna lutea		×					×									×
Vitex parviflora	×				×								×	×		
Vitex trifolia *	×				×								×		×	
Waltheria americana			×								×	×				×
Wedelia biflora		×					×						×		×	
Wendlandia luzonensis	×					×							×	×		
Wrightia laniti			×			×							×	×		
Zornia diphylla *		×						×	×			×				×
Totals	96	128	55	13	83	60+	26+	14	39+	21	60	87	211	46	150	96

ANNOTATED LIST OF THE SPECIES OF PTERIDOPHYTES AND SPERMATOPHYTES FOUND ON VOLCANO ISLAND SINCE THE ERUPTION OF TAAL VOLCANO IN 1911 [44]

POLYPODIACEAE

Acrostichum aureum Linn.* *Lagólo.* A few plants were observed on cliffs in sheltered ravines; none seen near the coast.

Adiantum caudatum Linn.* Widely scattered on bluffs near the shore.

Adiantum philippense Linn. *Culantrillo.* Scattered in shaded ravines.

Blechnum orientale Linn.* Abundant in some ravines at the northern end of the Island.

Ceropteris calomelanos (Linn.) Und.* Widely distributed on cliffs and in ravines, locally abundant; one plant was observed nearly at the crater rim, and a few within the crater near the base of the northeastern wall.

Cheilanthes tenuifolia (Burm. f.) Sw.* Widely scattered on earth banks and in ravines.

Dryopteris parasitica (Linn.) O. Kuntze.* Rare, a few juvenile plants in ravines.

Hemionitis arifolia (Burm. f.) Moore.* Widely scattered in ravines.

[44] In this list those species marked with an asterisk are additions to the list of Taal plants published by Gates in 1914; the dagger indicates those species recorded by Gates in 1914 that were not observed on Volcano Island in 1916–1917.

Microlepia speluncae (Linn.) Moore.* Widely scattered in ravines; not common.

Nephrolepis biserrata Schott. Widely distributed in ravines, open slopes, etc.; a single plant was observed just below the crater rim on the inside of the crater, and one at the base of the crater on the northeastern wall.

Notholaena densa J. Sm.* On bluffs near the beach and on walls of cañons; not abundant and very local.

Odontosoria chinensis (Linn.) J. Sm. Noted especially in ravines and cañons, locally abundant; a few plants in the crater on the northeastern wall.

Onychium siliquosum (Desv.) C. Chr. In ravines and cañons; local and not abundant.

Pteris vittata Linn. (*P. longifolia* Auct., non Linn.). On cliffs and walls of cañons; local.

Pteris quadriaurita Retz. In shaded ravines; local.

Stenochlaena palustris (Burm. f.) Bedd.* *Hagnáya.* A few plants observed back of the beach, in thickets, near Pirapiraso.

GLEICHENIACEAE

Gleichenia linearis (Burm. f.) Bedd.* A few juvenile plants observed in one ravine.

SCHIZAEACEAE

Lygodium japonicum (Thunb.) Sw. *Níto.* Widely scattered in thickets and in ravines; a few plants occur within the crater near the base of the northeastern wall.

Lygodium scandens (Linn.) Sw.* *Níto.* Not uncommon in thickets about Pirapiraso.

LYCOPODIACEAE

Lycopodium cernuum Linn.* A few juvenile plants observed on damp walls of a single cañon.

SELAGINELLACEAE

Selaginella belangeri Bory. On banks and among *Saccharum;* locally common.

PANDANACEAE

Pandanus tectorius Soland. *Pandán.* A few widely scattered individuals on open slopes; rare.

HYDROCHARITACEAE

Ottelia alismoides (Linn.) Pers.* *Calabáo.* Abundant along the northern coast, cast up by the waves.

Vallisneria gigantea Graebn. *Cíntas.* Apparently abundant in shallow water of coves and bays, as the plant is cast up on the beach in large quantities.

GRAMINEAE

Andropogon fragilis R. Br.* Rare.

Bambusa blumeana Schultes f. *Cauáyan totóo.* A number of tufts near Pirapiraso and a few in other localities, all from previous cultivation.

Bambusa vulgaris Schrad.* *Tianaúac.* A few tufts at Pirapiraso; all from previous cultivation.

Cynodon dactylon (Linn.) Pers. *Grama.* Widely scattered in damp soil near the beach.

Dactyloctenium aegyptium (Linn.) Richt. Widely scattered at low altitudes; not common.

Digitaria consanguinea Gaudich. Widely scattered at low altitudes at the northern end of the Island.

Digitaria ciliaris (Retz.) Pers.* With the preceding species, but less common.

Eleusine indica (Linn.) Gaertn. Scattered along the northern coast of the island.

Eragrostis amabilis (Linn.) W. & A. (*E. tenella* R. & S.).* Widely scattered along the beach.

Eragrostis distans Hack.* Not uncommon on dry banks of ravines at low altitudes.

Imperata cylindrica var. **koenigii** Benth. *Cógon.* Locally abundant, especially at the northern end of the island; in some places gregarious.

Miscanthus sinensis Anders. In widely scattered tufts; nowhere abundant or gregarious.

Oplismenus compositus (Linn.) Beauv.* Abundant in a few places at Pirapiraso.

Oryza sativa Linn.† *Bigás.* "One specimen seen." (Gates.) Not found in 1916–17.

Panicum carinatum Presl.* Abundant in ravines and thickets.

Panicum caudiglume Hack. At the base of bluffs along the coast and on the walls of cañons; locally abundant.

Panicum distachyum Linn. Widely scattered in damp soil at low altitudes.

Panicum repens Linn. In damp soil near the beach.

Paspalum distichum Linn. Gregarious in limited areas immediately back of the beach.

Paspalum scrobiculatum Linn. Widely scattered at low altitudes.

Phragmites vulgaris (Lam.) Trin. *Tambó.* Confined to very limited areas immediately on or back of the beach; nowhere abundant, and apparently rapidly being eliminated by other vegetation.

Pogonatherum paniculatum (Lam.) Hack.* On damp cañon walls; very local and not abundant.

Rottboellia exaltata Linn.* *Aguíngay.* A coarse annual grass of rare and local occurrence at low altitudes.

Saccharum spontaneum Linn. subsp. *indicum* Hack. *Taláhib.* Dominent nearly everywhere where vegetation occurs, except in the dense thickets and ravines where shrubs and small trees occur; on the upper slopes usually dwarfed and often from 20 to 30 cm. high. The only conspicuous plant within the crater, here widely scattered and usually dwarfed.

Themeda gigantea (Cav.) Hack. Locally abundant, in some places gregarious, and widely distributed on open slopes.

CYPERACEAE

Bulbostylis barbata Kunth. Abundant among *Saccharum* and in the beds of water courses.

Cyperus compressus Linn. Widely scattered among *Saccharum* in damp places.

Cyperus diffusus Vahl. Common in some ravines and in some thickets.

Cyperus distans Linn. Widely scattered; not common.

Cyperus radiatus Vahl.† "Local on the strand." (Gates.) Not observed in 1916–17.

Cyperus rotundus Linn.* Widely scattered at low altitudes.

Cyperus uncinatus Poir.* Widely distributed among *Saccharum* at low altitudes.

Fimbristylis merrillii Palla.* Rare in damp open places at low altitudes.

Fimbristylis polytrichoides R. Br.* Widely scattered in damp places at low altitudes; not common.

Fimbristylis squarrosa Vahl.* Widely distributed; locally abundant along the shore and in some ravines; scattered tufts occur within the crater.

Kyllinga monocephala (Linn.) Rottb.* A few plants observed at the base of bluffs along the beach.

Mariscus stuppeus (Forst.) Merr. Scattered along the beach and in some ravines.

Pycreus nitens (Vahl) Nees.* At the base of bluffs back of the beach; very local.

Pycreus holosericeus (Link.).* A few plants in damp soil along the strand.

Pycreus odoratus (Linn.) Urb.* Widely scattered at low altitudes.

Torulinium ferax L. C. Rich.* A single plant back of the beach on the west coast of the island.

ARACEAE

Amorphophallus campanulatus Roxb. *Poñgápong.* A few plants observed in ravines near Pirapiraso.

Pistia stratiotes Linn. *Quiápo.* Very local on the island for want of proper habitat; confined to a very few areas where stagnant water is found back of the beach. Commonly cast up on the beach by the waves.

LEMNACEAE

Lemna trisulca Hegelm.† *Lía.* "Washed up on the shore with *Pistia.*" (Gates.) Not seen in 1916–17.

Spirodela polyrrhiza (Linn.) Schleid.* *Lía.* Rare and in small quantity on stagnant water at mouths of water courses.

PALMAE

Arenga saccharifera Labill. *Cáong.* A few young plants observed in ravines.

COMMELINACEAE

Aneilema malabaricum (Linn.) Merr.* Rare at low altitudes.

Commelina benghalensis Linn.* *Alicbáñgon.* In damp soil at low altitudes; rare.

Commelina nudiflora Linn. *Alicbáñgon.* Widely scatterred in thickets and ravines at low altitudes.

Cyanotis cristata (Linn.) R. & S.* Locally abundant in thickets near the beach.

DIOSCOREACEAE

Dioscorea bulbifera Linn. In thickets and ravines; rare.

Dioscorea luzoniensis Scharuer. *Cobag.* In thickets and ravines; common about Pirapiraso.

Dioscorea myriantha Kunth.* Rare; only a few plants observed.

Dioscorea triphylla Linn. (*D. daemona* Roxb.).* *Nami.* In thickets and ravines at Pirapiraso.

Dioscorea aculeata Linn.* *Tugui.* In thickets on bluffs along the northern coast of the island.

MUSACEAE

Musa sapientum Linn. var. *Ságuing.* Two forms or varieties occur on the island, both certainly persistent from plants existing before the eruption.

ORCHIDACEAE

Eulophia squalida Lindl.* Rare; observed in one ravine.

Hetaeria oblongifolia Blume.* A single juvenile plant observed in a damp cañon on the northern slope of the volcano.

ULMACEAE

Trema orientalis Blume (*T. amboinensis* auct., non Blume). *Hanarión.* Common and widely distributed.

MORACEAE

Allaeanthus luzonicus (Blanco) F.-Vill. *Himbabaó.* One tree observed near Pirapiraso.

Artocarpus lamellata Blanco (*A. nitida* Trécul.). *Anóbling.* A few trees observed near Pirapiraso.

Ficus concinna Miq.* *Baléte.* A single juvenile plant observed.

Ficus cumingii Miq. *Isis.* Widely scattered on open slopes and in ravines. A polymorphous species, presenting several forms, some of which intergrade with *F. ulmifolia* Lam.

Ficus hauili Blanco. *Hauíli.* Common and widely distributed in thickets, ravines, and open slopes at low altitudes.

Ficus indica Linn. *Baléte.* Widely distributed. Certainly persistent from trees existing before the eruption; one well-established tree, perhaps 4 or 5 meters high, occurs on the northern crater wall inside the crater. This may prove to be *F. retusa* Linn.

Ficus nervosa Heyne.† "Small shrub in parang." (Gates.) Not observed in 1916–17.

Ficus nota (Blanco) Merr.* *Tibíg.* Rare; a few plants at low altitudes.

Ficus odorata (Blanco) Merr.* *Paquiling.* Rare; a single tree observed.

Ficus tinctoria Forst. *Baléte na bató.* On cliffs along the coast; widely scattered.

Ficus stipulosa Miq.* *Baléte.* A single tree on the bluffs near the northern coast of the island.

Ficus ulmifolia Lam. *Isís.* Common and widely distributed.

Malaisia scandens (Lour.) O. Kuntze.* *Malaisís.* A few plants in thickets near Pirapiraso.

Streblus asper Lour. *Caliós.* Rare in thickets at low altitudes.

URTICACEAE

Boehmeria blumei Wedd.* Scattered in ravines.

Pipturus arborescens (Link.) C. B. Rob. *Dolónot.* Widely scattered in thickets at low altitudes.

Pouzolzia zeylanica (Linn.) Benn.* A few plants in damp open places at low altitudes; rare.

ARISTOLOCHIACEAE

Aristolochia tagala Cham.* *Malaúbi.* Not uncommon in thickets near Pirapiraso.

POLYGONACEAE

Polygonum barbatum Linn.* A few specimens observed immediately back of the beach on the eastern coast of the island.

AMARANTHACEAE

Aerua lanata (Linn.) Juss.† A few small plants observed by Gates near the strand; not seen in 1916–17.

Alternanthera sessilis (Linn.) R. Br. Scattered near the beach.

Amaranthus spinosus Linn. *Colítis.* Widely scattered near the beach.

Deeringia baccata (Retz.) Moq. Not uncommon in thickets near Pirapiraso; scattered in other parts of the island.

AIZOACEAE

Trianthema monogyna Linn.* A single plant near the beach on the eastern coast of the island.

PORTULACACEAE

Portulaca oleracea Linn. *Golisíman.* Along the beach; rare and widely scattered.

CERATOPHYLLACEAE

Ceratophyllum demersum Linn. A submerged aquatic cast up on the shore.

MENISPERMACEAE

Cissampelos pareira Linn. Scattered in thickets at the northern end of the island.

Pericampylus incanus Miers. In thickets near Pirapiraso.

ANNONACEAE

Annona reticulata Linn.* *Anónas.* One mature tree, bearing fruits, and a few small ones near Pirapiraso; a remnant from old cultivation.

LAURACEAE

Cassytha filiformis Linn. *Malabohóc.* In thickets near the beach at a few places along the western shore of the island.

Litsea glutinosa (Lour.) C. B. Rob. *Pusopuso.* Widely scattered in thickets, on open slopes, and in ravines.

CAPPARIDACEAE

Capparis horrida Linn. *Dauág.* In thickets and ravines; locally abundant.

Capparis micracantha DC. *Halobágat.* Much less common than the preceding species.

Crataeva religiosa Forst.† "Tree, invading parang." (Gates.) Not observed in 1916–17.

Polanisia viscosa DC. A few plants observed immediately back of the beach; widely scattered.

MORINGACEAE

Moringa oleifera Lam. *Malúngay.* Near Pirapiraso; a few trees, almost certainly persisting from before the eruption.

CONNARACEAE

Cnestis diffusa (Blanco) Merr.* Not uncommon in thickets along the northern coast of the island.

Rourea erecta (Blanco) Merr. *Camagsá.* In thickets and ravines; widely scattered but not abundant.

LEGUMINOSAE

Abrus precatorius Linn. *Saga.* Widely scattered at low altitudes.

Acacia farnesiana (Linn.) Willd. *Aróma.* Abundant.

Albizzia procera (Roxb.) Benth. *Acleng párang.* Common on slopes and in ravines at the northern end of the island.

Alysicarpus vaginalis DC. *Manimanihan.* Fairly common among *Saccharum* at low altitudes.

Arachis hypogaea Linn. *Maní.* A few plants observed by Gates near Pirapiraso, and one or two in 1916–17.

Caesalpinia crista Linn.* *Calumbibít.* Scattered in thickets at low northern end of the island.

Canavalia ensiformis (Linn.) DC., forma. Abundant near the coast in ravines and thickets.

Canavalia lineata DC. *Patáning dágat.* Locally abundant along the beach.

Cantharospermum scarabaeoides (Linn.) Baill. Widely scattered among *Saccharum* at low altitudes.

Cassia alata Linn.* *Capúrco.* Rare; a few plants observed at low altitudes.

Cassia tora Linn.* *Catandáng áso.* Rare; a few plants observed at low altitudes.

Clitoria ternatea Linn.* A few plants at low altitudes; rare.

Crotalaria albida Heyne. Locally abundant among *Saccharum* at low altitudes.

Crotalaria acicularis Ham.* Locally abundant among *Saccharum* at low altitudes.

Crotalaria stenophylla Vog.* Widely scattered among *Saccharum* at low altitudes.

Crotalaria verrucosa Linn.* Rare; a few plants observed near the beach.

Derris polyantha Park. Common in thickets along the northern coast of the island.

Desmodium gangeticum (Linn.) DC. Widely distributed and common among *Saccharum* at low altitudes.

Desmodium procumbens Hitchc.* Rare; only a few plants observed.

Desmodium pulchellum Benth. Common among *Saccharum* at low altitudes.

Desmodium scorpiurus (Sw.) Desf. Common among *Saccharum* at low altitudes.

Desmodium triflorum (Linn.) DC. Common and widely distributed at low altitudes.

Erythrina indica Lam. *Dapdap.* Widely scattered; chiefly near the coast; rare.

Gliricidia sepium (Jacq.) Steud. *Madre cacáo.* Locally abundant; at the northern end of the island; probably persistent from trees existing before the eruption.

Mezoneurum latisiliquum (Cav.) Merr. *Cámot púsa.* On bluffs along the coast; not common.

Mucuna nigricans (Lour.) Steud.* *Nípai.* A few plants in thickets at the northern end of the island near the beach.

Pachyrrhizus erosus (Linn.) Urb. *Síncamas.* A few specimens observed in thickets at low altitudes; Gates observed a single plant.

Phaseolus adenanthus Mey.* Common and conspicuous in thickets along the northern and western coasts.

Pithecolobium dulce (Roxb.) Benth. *Camanchíle.* Widely distributed in ravines and thickets; almost certainly persistent from trees existing before the eruption.

Pongamia pinnata (Linn.) Merr. (*Millettia* sp., of Gates's list). *Balíc-balíc.* In ravines and thickets at low altitudes; not common.

Pueraria phaseoloides Benth.* In thickets and in *Saccharum* areas; widely scattered.

Samanea saman (Jacq.) Merr. (*Pithecolobium saman* Benth.).* *Acacia.* A single seedling observed back of the beach on the western coast.

Sesbania cannabina (Retz.) Pers. A few seedling observed on the eastern coast back of the beach; Gates reports it as abundant in one place in the northeastern part of the island.

Tephrosia dichotoma Desf. Widely distributed in *Saccharum* areas at low altitudes in the northern part of the island; locally abundant.

Vigna lutea A. Gray. Widely distributed in thickets along the beach.

Zornia diphylla Pers.* Locally abundant in talahib areas at low altitudes.

EUPHORBIACEAE

Antidesma bunius (Linn.) Spreng. *Bignay.* Scattered in thickets near Pirapiraso and in other parts of the island.

Antidesma ghaesembilla Gaertn. *Bignay pogo.* On lower slopes, in thickets, and in ravines; common and widely scattered, especially in the northern end of the island.

Antidesma rostratum Tul.† *Bignay pogo.* A few small trees recorded by Gates; not observed in 1916–17.

Breynia acuminata Muell.-Arg. *Matang ulang.* Scattered in thickets near Pirapiraso; a specimen collected by Gates was identified as *Phyllanthus reticulatus* Poir.

Breynia cernua (Poir.) Muell.-Arg. *Matang ulang.* In thickets near Pirapiraso.

Breynia rhamnoides (Retz.) Muell.-Arg. *Matang ulang.* In thickets near Pirapiraso, rare.

Bridelia stipularis (Linn.) Blume. *Lubálub.* Abundant in thickets at the northern end of the island.

Euphorbia hirta Linn.* *Botóbotónes.* Widely scattered near the coast; not common.

Fluggea virosa (Willd.) Baill. *Botólan.* Common in thickets, especially about Pirapiraso.

Glochidion rubrum Blume.* Rare; a few shrubs observed.

Glochidion triandrum (Blanco) C. B. Rob. Not uncommon in thickets near Pirapiraso.

Macaranga tanarius (Linn.) Muell.-Arg. *Binóñga.* Widely scattered in thickets and ravines.

Mallotus moluccanus Muell.-Arg. *Álim.* In thickets and ravines; widely scattered; locally common.

Manihot utilissima Pohl. *Camóting cáhoy.* A few plants observed in ravines near Pirapiraso, tending to become exterminated by the encroaching native vegetation; almost certainly persistent from plants existing before the eruption.

Phyllanthus erythrotrichus C. B. Rob. On bluffs near the coast, in ravines, and in thickets; widely distributed.

Ricinus communis Linn. *Táñgan-táñgan.* Widely scattered at low altitudes; mostly confined to the immediate vicinity of the beach.

ANACARDIACEAE

Dracontomelum cumingianum Baill.* *Lámio.* Only one tree observed.

Semecarpus cuneiformis Blanco. *Ligás.* Widely distributed on slopes and in ravines; almost certainly persistent from trees existing before the eruption.

CELASTRACEAE

Celastrus paniculata Willd. Not uncommon in thickets at the northern end of the islands.

SAPINDACEAE

Arytera littoralis Blume.* A few old trees near Pirapiraso.

Erioglossum rubiginosum (Roxb.) Blume.* In thickets near the coast at the northern end of the island; a few rather large specimens.

Otophora fruticosa Blume.* *Balinóno.* In thickets at Pirapiraso, locally common.

VITACEAE

Cissus repens Lam. *Pirápit hángin.* Widely scattered in thickets and in ravines; not common.

Columella (Cissus) trifolia (Linn.) Merr. *Calít-calít.* In ravines at low altitudes; scattered.

Tetrastigma harmandii Planch. *Ayo.* Scattered in ravines and thickets at low altitudes near Pirapiraso.

ELAEOCARPACEAE

Muntingia calabura Linn.† *Dátiles.* "Seedlings on the beach and trees in the parang on the slopes of Mount Ragatan." (Gates.) Not seen in 1916–17.

TILIACEAE

Corchorus acutangulus Lam.* *Pasáo-na-habá.* A few plants observed back of the beach at one place only.

Triumfetta bartramia Linn. *Colót colótan.* Widely scattered among *Saccharum* at low altitudes.

MALVACEAE

Hibiscus surattensis Linn.* A few plants found along the beach at the northern end of the island.

Sida acuta Burm. f. *Escóbang habá.* Widely scattered at low altitudes; nowhere common.

Sida rhombifolia Linn. Scattered at low altitudes; not common.

Urena lobata Linn.* *Colót colótan.* Scattered in the *Saccharum* areas, but not abundant.

BOMBACACEAE

Ceiba pentandra (Linn.) Gaertn. *Bóboy.* Widely scattered in thickets and ravines; the older trees almost certainly persisting from plants growing before the eruption.

STERCULIACEAE

Sterculia foetida Linn. *Calumpang.* Widely scattered on grassy slopes; certainly persisting from trees existing before the eruption.

Waltheria americana Linn. Widely distributed in the *Saccharum* areas at low altitudes.

GUTTIFERAE

Cratoxylon blancoi Blume. *Gúyong-gúyong.* Widely scattered; Gates observed this sprouting from buried stumps.

FLACOURTIACEAE

Casearia cinerea Turcz. Common in thickets and ravines at low altitudes.

Flacourtia rukam Z. & M.* Rare and local; a few plants observed.

CARICACEAE

Carica papaya Linn. *Papaya.* Scattered in ravines and thickets at low altitudes, especially at the northern end of the island.

THYMELAEACEAE

Phaleria cumingii F.-Vill.† "A vine in parang thicket; infrequent." (Gates.) Not seen in 1916–17. Gates's specimen is sterile, but the identification is apparently correct, although the plant is not a vine.

ELAEAGNACEAE

Elaeagnus philippensis Perr.† *Alingaró.* "Vine in parang; infrequent." (Gates.) Not observed in 1916–17.

COMBRETACEAE

Quisqualis indica Linn. *Nióg niógan.* Along the northern coast and in thickets about Pirapiraso.

Terminalia catappa Linn.* *Talísay.* A few young trees observed; widely scattered back of the beach.

MYRTACEAE

Eugenia jambolana Lam. *Duhat.* Widely distributed in thickets and in some ravines; common. This is almost certainly persistent from trees existing before the eruption, as some plants were found where the shoots had grown from the broken trunks of very old trees, in one case the old trunk being 40 cm in diameter.

Psidium guajava Linn. *Bayabas.* Widely distributed at low altitudes; common.

OENOTHERACEAE

Jussiaea repens Linn. A few juvenile plants observed in damp soil near the beach.

Jussiaea linifolia Vahl.* A few widely scattered individuals observed along the beach.

UMBELLIFERAE

Centella asiatica (Linn.) Urb.* *Taquip cohól.* Abundant locally, in damp soil back of the beach at the northern end of the island.

MYRSINACEAE

Maesa cumingii Mez. Not uncommon in ravines and in thickets at the northern end of the island; widely scattered.

Maesa laxa Mez.* Less common than than the preceding species.

LOGANIACEAE

Buddleia asiatica Lour. Scattered on bluffs near the beach.

Mitrasacme alsinoides R. Br.* Widely scattered among *Saccharum* at low altitudes; on the walls of cañons and ravines.

APOCYNACEAE

Aganosma acuminata G. Don.* A few plants on slopes and in ravines near Pirapiraso.

Alstonia macrophylla Wall.* *Batino.* Rare; only one or two young trees observed.

Alstonia scholaris (Linn.) R. Br. *Ditá.* Very widely scattered at the northern end of the island.

Tabernaemontana pandacaqui Poir. *Pandacáqui.* Locally abundant in thickets and in ravines.

Tabernaemontana subglobosa Merr. *Pandacáqui.* More abundant and more generally distributed than the preceding species.

Wrightia laniti (Blanco) Merr. *Laníti.* Widely distributed in ravines, thickets, and sometimes on open slopes, not abundant.

ASCLEPIADACEAE

Calotropis gigantea R. Br.* *Capól-capól.* A few individuals at low altitudes; rare.

Gymnema pachyglossum Schltr. In thickets near the shore at the northern end of the island; locally common.

Gymnema tingens W. & A.† (*Parsonsia ?* of Gates's list.) "A small vine in the parang." (Gates.) Not found in 1916–17.

Streptocaulon baumii Dcne. Common in thickets and widely distributed.

Tylophora perrottetiana Dcne.* In thickets along the northern coast; rare and widely scattered.

CONVOLVULACEAE

Calonyction album (Linn.) House.* In thickets at the northern end of the island, especially near the coast; ascending to the tops of the hills near Pirapiraso.

Hewittia sublobata (Linn. f.) O. Kuntze. Widely scattered at the northern end of the island at low altitudes; locally abundant.

Ipomoea batatas (Linn.) Poir.† *Camote.* "A few vines near Pirapiraso." (Gates.) Not seen in 1916–17.

Ipomoea obscura (Linn.) Ker. Widely distributed on slopes at low altitudes; not abundant.

Ipomoea pescaprae (Linn.) Roth. *Lampáyong.* In many places abundant on the beach; in some places extending inland up slopes for considerable distances.

Ipomoea paniculata R. Br.* In thickets near the beach; widely scattered.

Ipomoea pestigridis Linn. Widely scattered at low altitudes in *Saccharum.*

Ipomoea reptans (Linn.) Poir.* *Cancóng.* A single plant observed in damp soil near the beach.

Ipomoea triloba Linn. Scattered at low altitudes; not common.

Operculina turpethum (Linn.) Manso. In thickets and ravines; widely scattered.

Stictocardia campanulata (Linn.) Merr.* Scattered in thickets along the northern coast of the island.

BORAGINACEAE

Cordia myxa Linn. (*C. blancoi* Vid.) *Anónang.* Widely scattered on slopes, in thickets, and in ravines; fairly common.

Heliotropium indicum Linn. *Trompa elefánte.* Widely scattered in damp soil near the beach; not common.

Tournefortia sarmentosa Lam. Not uncommon in thickets at the northern end of the island.

Trichodesma zeylanicum R. Br.* A number of plants were observed in one locality near the beach east of Pirapiraso.

VERBENACEAE

Callicarpa blancoi Rolfe. *Tubang dalág.* Abundant and widely distributed on open slopes and in ravines.

Clerodendron minahassae T. & B. *Bagáuac.* Widely scattered at low altitudes, in thickets and in ravines.

Gmelina philippensis Cham.* *Alípung.* Widely scattered on open slopes; not abundant.

Premna nauseosa Blanco. *Alagáo.* On open slopes; widely scattered.

Premna odorata Blanco.* *Alagáo.* In thickets and ravines near Pirapiraso.

Vitex parviflora Juss. *Moláve.* One tree observed by Gates; collected in 1916; rare.

Vitex trifolia Linn.* *Lagúndi.* Rare; a few plants at low altitudes.

LABIATAE

Anisomelis indica (Linn.) O. Kuntze.* *Talingharáp.* Scattered in ravines and thickets near Pirapiraso.

Hyptis suaveolens (Linn.) Poir.* *Soob cabáyo.* A few plants observed at Pirapiraso.

Leucas javanica Blume. Widely scattered in grasslands at low altitudes; not common.

SOLANACEAE

Capsicum fruticosum Linn.* *Sili.* Widely scattered in ravines and thickets near Pirapiraso.

Datura alba Nees. *Talampúnai.* Scattered in low lands near the coast, especially near Pirapiraso.

Lycopersicum esculentum Mill. *Camátes.* A few, widely scattered, fruiting specimens observed at low altitudes; the wild form with small fruits.

Physalis minima Linn.* Scattered individuals near the coast in the vicinity of Pirapiraso.

Solanum cumingii Dunal.* A few plants in open places at low altitudes; rare.

Solanum nigrum Linn.* A few plants observed near the beach.

Solanum verbascifolium Linn.* Widely scattered at the northern end of the island; not common.

SCROPHULARIACEAE

Bonnaya brachiata L. & O.* Widely scattered at low altitudes among *Saccharum*.

Lindenbergia philippensis (Cham.) Benth. Local; observed only on the walls of cañons and ravines.

Pyxidaria pusilla (Thunb.) Merr. (*Vandellia pusilla* Merr., *V. scabra* Benth.) Local among grasses in open damp soil.

Pyxidaria crustacea (Linn.) F. Muell. Widely scattered at low altitudes.

Scoparia dulcis Linn. Widely scattered at low altitudes; nowhere common.

Torenia peduncularis Benth.* A single plant near Pirapiraso.

BIGNONIACEAE

Oroxylum indicum (Linn.) Vent. *Pincapincahan.* Widely scattered; nowhere abundant.

ACANTHACEAE

Blechum brownei Nees.* Scattered in thickets near Pirapiraso; rare.

Hemigraphis rapifera Hallier f.* A few plants observed in ravines.

Hygrophila angustifolia R. Brown.* *Mamitic.* A few juvenile plants in damp soil back of the beach.

RUBIACEAE

Hedyotis tenelliflora Blume.* Rare; a few plants observed in open damp soil.

Morinda bracteata Roxb. *Bancúdo.* Common and widely distributed.

Mussaenda philippica L. C. Rich.* *Cáhoy dalága.* Scattered in thickets near Pirapiraso; fully matured individuals in full anthesis.

Neonauclea bartlingii (DC.) Merr.* A single seedling observed in damp ravine on the outer slopes of the crater rim and two or three near the base of the northeastern wall inside of the crater.

Oldenlandia corymbosa Linn. Widely scattered at low altitudes, but not abundant.

Spermacoce hispida Blume. Widely scattered; not common.

Wendlandia luzonensis DC. In ravines near Pirapiraso; widely scattered.

CUCURBITACEAE

Bryonopsis laciniosa Naud.* Widely scattered in thickets near the beach; rare.

Citrullus vulgaris (Linn.) Schrad.† *Pacúan.* "Local on the strand." (Gates.) Not found in 1916–17.

Cucurbita maxima Duch.* *Calabáza.* A single young plant observed back of the beach along the western shore of the island.

Luffa cylindrica (Linn.) Roem. *Patóla.* Widely scattered, especially near the beach; the wild form.

Melothria mucronata (Blume) Cogn.* In thickets near Pirapiraso; not common.

Momordica charantia Linn. *Ampalaya.* Widely scattered at low altitudes; not abundant.

Momordica cochinchinensis (Lour.) Spreng. *Búyoc-búyoc.* In thickets and ravines; fairly common at the northern end of the island.

Mormordica ovata Cogn. *Búyoc-Búyoc.* Associated with the preceding but more abundant; this differs from the preceding only in its entire, not lobed leaves and is probably not specifically distinct.

COMPOSITAE

Ageratum conyzoides Linn. *Bulac manóc.* Common among *Saccharum* at low altitudes.

Blumea balsamifera (Linn.) DC. *Sambóng.* Locally abundant in ravines etc.; only three plants observed by Gates.

Blumea lacera DC. Widely scattered in ravines and among coarse grasses; a few plants inside of the crater.

Blumea mollis (Don) Merr.* Widely scattered at low altitudes, especially in ravines.

Blumea glomerata DC.* Abundant on the walls of a single damp ravine at the northern end of the island.

Eclipta alba (Linn.) Hassk. Widely scattered at low altitudes near the beach.

Eclipta zippeliana Blume.* A few plants observed near the beach at the northern end of the island.

Emilia sonchifolia (Linn.) DC. In ravines at low altitudes; widely scattered, but not abundant.

Erigeron linifolius Willd. Widely scattered at low altitudes; not abundant; a few plants inside the crater.

Pterocaulon cylindrostachyum C. B. Clarke. On dry open slopes; locally abundant, but of very limited distribution.

Sphaeranthus africanus Linn.* Two or three plants observed back of the beach along the northern coast of the island.

Synedrella nodiflora (Linn.) Gaertn. Rare and very widely scattered at low altitudes.

Vernonia cinerea (Linn.) Less. Widely distributed, but nowhere abundant.

Vernonia patula (Ait.) Merr.* A few widely scattered individuals were observed, chiefly near the beach at the northern end of the island.

Wedelia biflora (Linn.) R. Br. *Hagonoy.* In thickets near the beach.

SUMMARY

The vegetation of Volcano Island before the eruption of 1911 consisted of a mixture of grass and small trees, which covered all parts of the island except the slopes of the main crater and Mount Tabaro and the dry stream beds.

The eruption of 1911 completely destroyed the vegetation over most parts of the island, while in the extreme northern part a few bamboos, bananas, trees, and possibly some grass escaped.

In the revegetation of the island a single species of grass, *Saccharum spontaneum,* is so much the most prominent of all the invaders that it gives character to the whole vegetation. Except in the northern part of the island, it occurs as scattered clumps. Besides *Saccharum* the other most conspicuous elements are scattered trees.

The revegetation is proceeding slowly owing, probably, to adverse environmental conditions, the most prominent of which are the presence of excessive amounts of sulphates in the soil; the lack of weathering of the soil particles; the scarcity or absence of humus; the scarcity of nitrogen; the low water-holding capacity of the soil; and erosion.

Two hundred ninety-two species of plants have been found on Volcano Island since the eruption. These represent 232 genera and 66 families.

Most of the species of plants on Volcano Island are those of wide geographic distribution. Ninety-six, or 36 per cent, are found in the tropics of both hemispheres, while an additional one hundred fifty, or 51 per cent, are found in other parts of the Indo-Malayan regions as well as in the Philippines.

Very few of the species of plants on Volcano Island have found favorable habitats over any considerable area, as only 13 are common and widely distributed.

Birds seem to have been the most important agency in bringing different species to Volcano Island, as 54 per cent of the total on the island could have been carried to it by this means.

ILLUSTRATIONS

PLATE IV

Relief map of Volcano Island before the eruption of 1911. The only changes caused by the last eruption that were of sufficient magnitude to show on this relief map are within the crater, the center of which is now occupied by a single large lake (Plate XVI, fig. 2). (Map prepared in the division of mines, Bureau of Science.)

PLATE V

FIG. 1. Photograph taken in December, 1909, to show erosion on the southwestern slopes of Taal Volcano. On the right is Taal Volcano, while Mount Tabaro is on the left. The center of the picture is occupied by the prominent dry stream bed extending southwest toward Mount Saluyan. In the foreground is a small ridge with scattered clumps of grass. The dry stream bed contains a few trees and very widely spaced clumps of grass. The slopes are apparently bare, but may have supported scattered tufts of grass.

2. View of the southeastern slopes of Volcano Island from Lake Bombon, April, 1908. The steep slopes of the main cone appear to be very bare, while the lower and more level ground is covered with vegetation in which trees predominate.

PLATE VI

FIG. 1. View of the southeastern shore of Volcano Island and Taal Volcano during the period of activity in 1911 and the day before the great eruption that destroyed the vegetation. Near the lake the vegetation consists largely of grass, while trees are more prominent farther inland.

2. The northern slopes of Mount Binintiang Malaqui at the northwestern point of Volcano Island, December, 1909. The cone is covered with vegetation in which trees are very prominent.

PLATE VII

FIG. 1. The effect of the mud blast on a tree at Gulod, on the mainland, about 8 kilometers from the crater. Natural size. (Photo by Martin.)

2. A tree 15 centimeters in diameter broken by the force of the eruption and the bark and wood shredded by the mud driven by the force of the eruption. (Photograph by Martin.)

PLATE VIII

FIG. 1. The site of the former village of Pirapiraso, in the northern part of the island, immediately after the eruption. Most of the trees in the foreground are broken off close to the ground; also on the hills in the background some of the trees are broken, and all of them are leafless. The ground between the beach and the hills is apparently covered with ash. (Photograph by Martin.)

2. View from the shore looking east toward the two old craters south of Mount Balantoc, October, 1916. The relative abundance and size of the clumps of *Saccharum* is well indicated. The ground between the clumps of *Saccharum* is sparsely covered by low or creeping grasses and sedges. A few bushes are seen in the background.

PLATE IX

FIG. 1. *Ipomoea pes-caprae* growing along the shore and upon the slopes between clumps of *Saccharum*. Southern shore of Volcano Island, west of Calauit Point, October, 1916.

2. Southern slopes of Mount Binintiang Malaqui, as seen from Guano Point. To the right in the foreground is the end of a deltal fan. The low ridge back of this is the western end of Mount Balantoc, which supports scattered clumps of grass and some trees. The trees on Mounts Balantoc and Binintiang Malaqui are seen as dark spots in the picture. The trees on the latter mountain are widely scattered. They are about as prominent on the other slopes of the mountain as in this picture. A comparison of this view, taken October, 1916, with Plate VI, fig. 2, shows that trees are much less abundant at the present time than before the eruption.

PLATE X

FIG. 1. The foot of Mount Balantoc, near the former town of Panipihan. (Photograph by Gates, April 18, 1914.)

2. South from the summit of Mount Binintiang Malaqui. In the foreground is a horseshoe ridge, Mount Balantoc; in the background, the crater with its high southern wall; in the extreme background is Mount Macolod on the mainland. In the background on the right from the center are Mounts Tabaro and Saluyan. The scattered nature of the vegetation on Mount Balantoc is very evident. (Photograph by Gates, April 18, 1914.)

3. View looking north from near the crater rim toward Mount Tibag in the north-central region. The vegetation is almost entirely *Saccharum spontaneum*. (Photograph by Gates. October 25, 1913.)

PLATE XI

View of the southern slope of the northwestern end of Mount Balantoc. The vegetation consists mostly of widely spaced clumps of *Saccharum spontaneum* with scattered trees. October, 1916.

The northwestern part of Volcano Island from the rim of the crater where M[illegible]ag-ulbua[illegible] joints the main cone. In the background Ridge on the mainland. The cone at the end is Mount Binintiang Malaqui. In front of

this is Mount Balantoc. In the foreground are the lower slopes of the main cone. The vegetation on Mount Binintiang Malaqui is largely *Themeda gigantea* and *Saccharum spontaneum*. The remainder of the vegetation shown consists very largely of an open stand of *Saccharum*. On Mount Balantoc are seen a considerable number of scattered trees. October, 1916.

PLATE XII

FIG. 1. The central region of the northern part of Volcano Island, from the crater rim where Mount Pinag-ulbuan joins the main cone. The prominent peak on the right is Mount Mataas-na-golod. On the extreme left is Mount Tibag. The vegetation throughout is very largely an open stand of *Saccharum spontaneum*. October, 1916.

2. The northwestern slopes of the southwestern peninsula of Volcano Island as seen from Malanao Point. On the right is Mount Binintiang Munti; on the left, Mount Saluyan. The dark spots represent scattered trees. The remainder of the vegetation is very largely an open stand of *Saccharum spontaneum*. On account of the distance at which the photograph was taken the bare ground between the clumps of *Saccharum* is not shown plainly. October, 1916.

PLATE XIII

FIG. 1. View of the southern portion of Volcano Island from Calauit Point. In the distance is the crater of Taal Volcano, the high portion on the left being the southwestern part of the rim. The vegetation consists almost entirely of very scattereing clumps of *Saccharum spontaneum*. October, 1916.

2. The prominent dry stream bed, extending southwest from the southwestern part of the rim of the crater. In the picture is seen that part of the stream bed where it curves around Mount Saluyan, the lower slopes of which are to the right. The effects of erosion are very evident. No plants occur in the dry stream bed. Elsewhere the vegetation consists almost entirely of very scattering clumps of *Saccharum spontaneum*, there being only about six shrubs visible in the picture. October, 1916.

PLATE XIV

FIG. 1. A deltal fan on the western side of Volcano Island. View from near Pandac-na-longos point toward the southeast. In the background on the left is the southwestern part of the ri[illegible]VILLA, P. I., crater; on the right is a low ridge, behind wh[illegible] a portion of the flattened top of Mount T[illegible] of the picture is a dry stream bed running [illegible]ew [illegible]e of June, The only vegetation seen on the[illegible], Stra[illegible] [illegible]ed when my clumps of *Saccharum* [illegible]t 0, Th[illegible] [illegible]s in page p[illegible] distance scattered cl[illegible] [illegible]nam[illegible] [illegible]cited in the Adde[illegible] October, 1916.

2. View of the source of the [illegible] 1905) 1–125.

X fig. 2, which extends f[illegible] MA[illegible] 249

cone toward Mount Saluyan. In the background on the left is Mount Tabaro, on the right is the main crater. The vegetation consist of a very sparse development of *Saccharum*, a few clumps of which are seen in the foreground. In the remainder of the area the tufts of *Saccharum* are too small and scarce to show in the picture. A comparison of this view with plate II, fig. 1, shows that vegetation was very scarce in this area before the eruption and consisted of a few trees or shrubs and small scattered clumps of a grass, probably *Saccharum spontaneum*.

PLATE XV

FIG. 1. The outer slopes of the crater of Taal Volcano as seen from the southeast. The effect of erosion on the topography is very marked. The vegetation is composed practically entirely of scattered clumps of *Saccharum spontaneum*. On the upper slopes *Saccharum* is reduced to very small tufts. October, 1916.

2. The crater of Taal Volcano, as seen from the southern rim. Owing to the steepness of the slope and the rapidity of erosion, the walls are largely bare. The gentle slopes within the crater support scattered clumps of *Saccharum spontaneum* and a few individuals of two sedges. October, 1916.

PLATE XVI

FIG. 1. A typical cañon on the slopes of Taal Volcano.

2. Effect of erosion on the southwestern slopes of Taal Volcano.

TEXT FIGURES

FIG. 1. Map of Volcano Island, Lake Bombon, and the surrounding country. (Depths and elevations are given in meters.)

2. Map published by Gates to show the revegetation of Volcano Island. The numbers indicate the plant associations as interpreted by Gates. 1, *Vallisneria* association, apparently indicated largely by fragments thrown up on the beach; 2, 3, 4, and 5 represent marsh or strand vegetation that has apparently disappeared through the action of erosion; 6, *Ipomoea pes-caprae*; 7, grass; 8 and 9, shrubs and trees, apparently occurring largely as scattered individuals.

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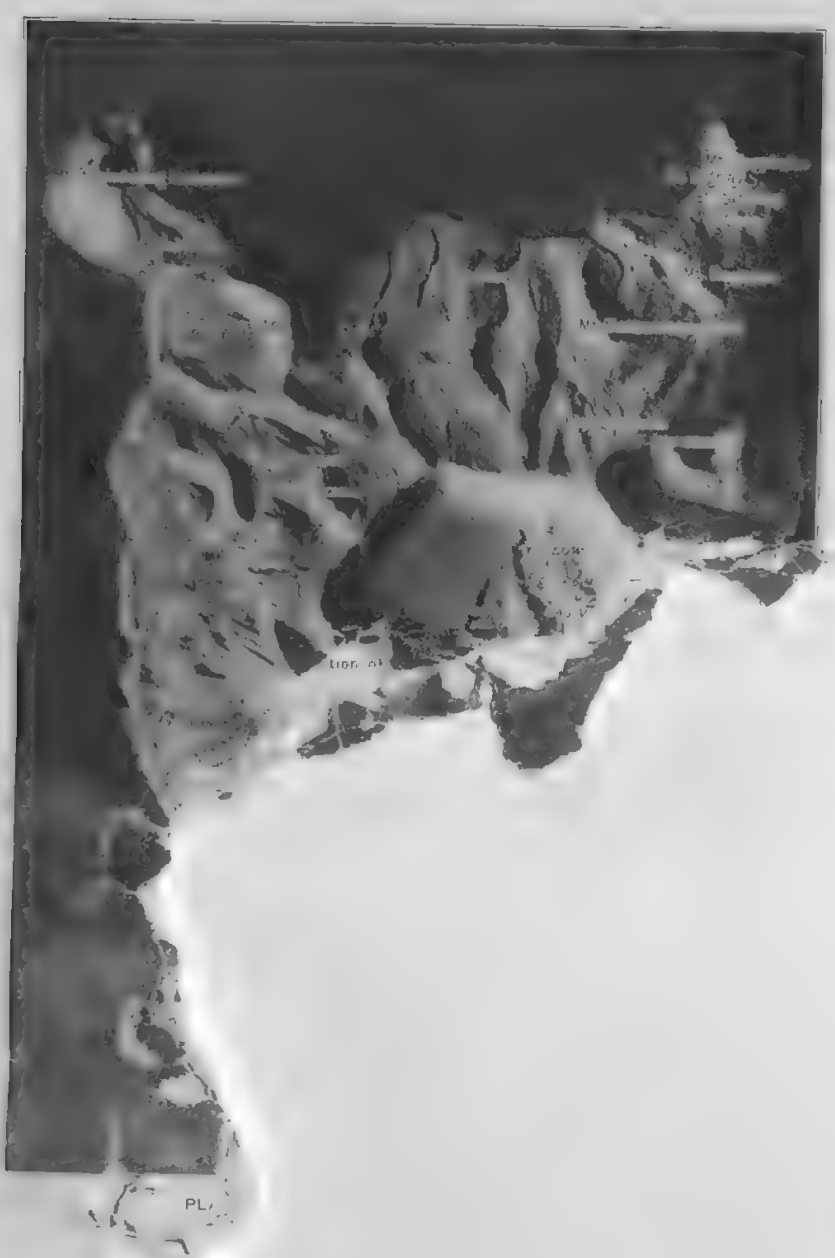


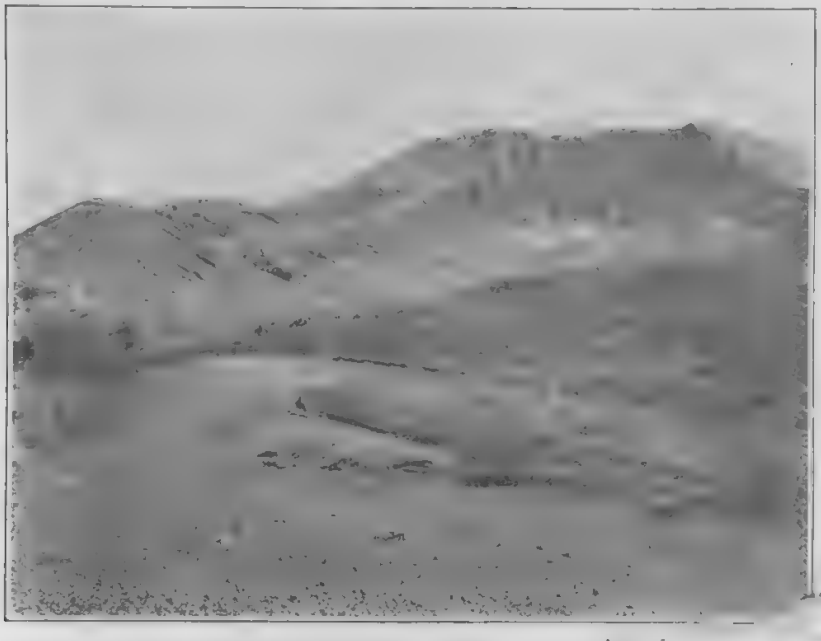
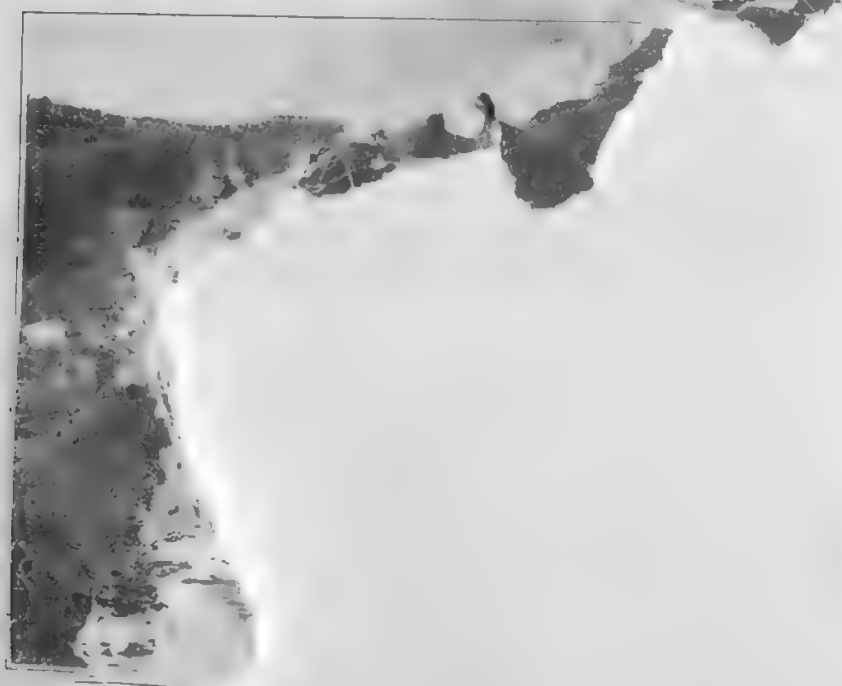


Fig. 1. Southeastern slopes of Taal Volcano in 190[illegible]

Fig. 1. Southeastern shore of Volcano Island

Fig. 1. The effect of the eruption on [illegible]

Fig. 1. Site of village of Pirapiraso after the eruption.



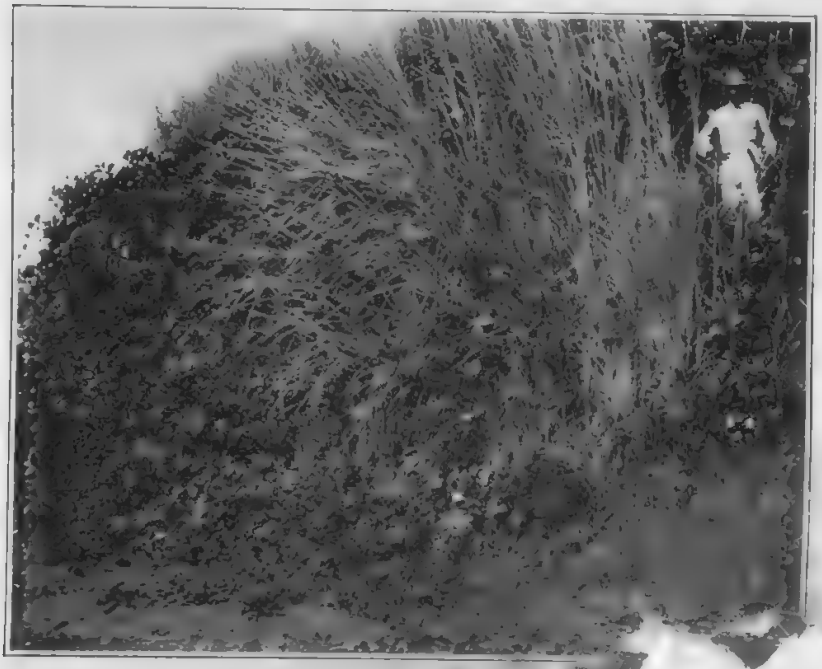


Fig. 1. Ipomoea pes-caprae and Saccharum sp

Fig. 1. Foot of Mount Balantoc in 1914.

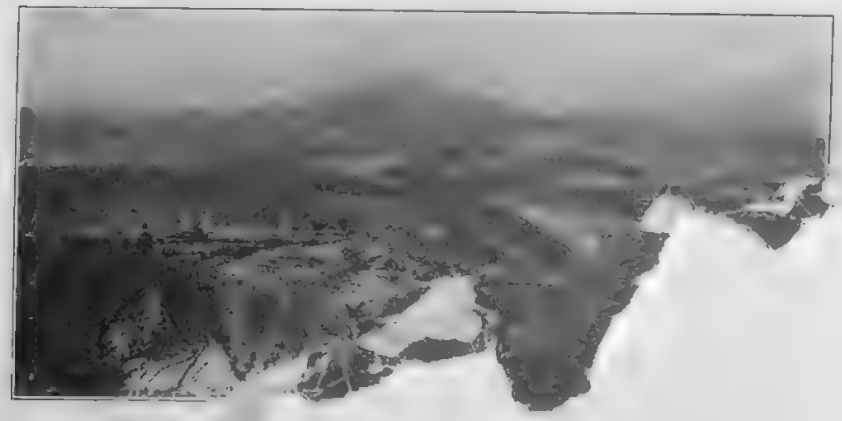


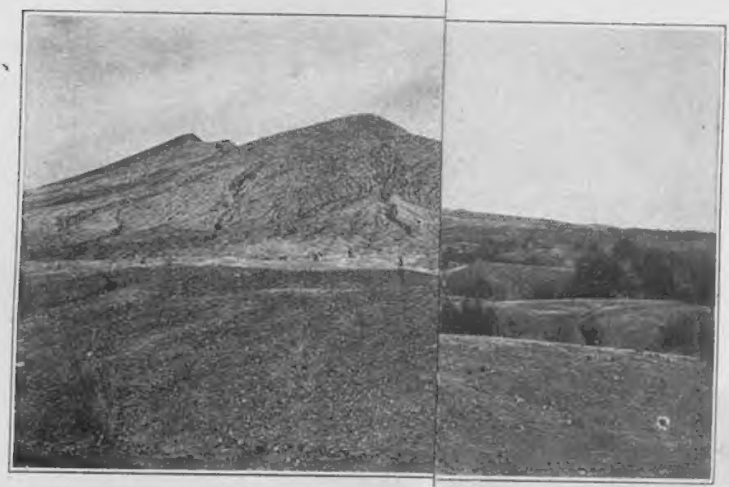
Fig.

Fig. 1. Vegetation on Mount Balantoc in 1916

Fig. 1. Mount Mataas-na

Fig. 1. Southern portion of Volcan

Fig. 2. A deltal plai



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Thacker, Spink & Co., P. O. Box 54, Calcutta, India.

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View of
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of *Saccharum spontan*
The northwestern part of
where M ag-ulbu
Ridge
is Mo r